HOLOCENE VOLCANISM AND HUMAN OCCUPATION IN THE MIDDLE SUSITNA RIVER VALLEY, ALASKA

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Abstract

Archaeological and stratigraphic evidence from the middle Susitna River Valley, Alaska, reveals a rich record of human occupation during the Holocene, punctuated by volcanic ash deposits locally referred to as the Devil, Watana, and Oshetna tephras. Deposition of tephra in the middle Susitna River Valley had the potential to affect subsistence resources and lifeways of prehistoric peoples; however, ambiguities remain in dating both tephra deposits and cultural occupations, and in characterization of the tephra deposits. In addition, there has been little formal consideration of how deposition of tephra may have affected prehistoric hunter-gatherers using the middle Susitna River Valley (mSRV) during the Holocene and this research seeks to fill that gap.

Electron probe microanalysis is used to geochemically characterize the middle Susitna River Valley tephra, enabling correlation to reference tephra from Hayes Volcano and aiding in determining the number of volcanic events present in the stratigraphic record of the middle Susitna River Valley. Assimilation of existing radiocarbon dates from multiple sources with new AMS radiocarbon dates produced as part of this study allows for estimating the timing of tephra deposition and evaluating the timing of cultural occupation of the area with greater precision. Characteristics of archaeological assemblages bounded by tephra deposits are also evaluated relative to existing frameworks for understanding prehistoric hunter-gatherer behavior in interior Alaska. Interpretation is aided by consideration of other tephra depositional events and their environmental and ecological effects.

Results suggest that at least four tephra depositional events took place in the middle Susitna River Valley. The Devil tephra was deposited between 1625–1825 cal yr B.P. (calibrated years before present). The Watana tephras, which correlate to the Hayes Volcano tephra set H, were deposited between 3360–4400 cal yr B.P., with the upper and lower portions of this tephra deposited either in rapid succession or separated in time by only a few hundred years. The Oshetna tephra was deposited between 6570–7970 cal yr B.P. While the Devil, upper and lower Watana tephras represent discrete volcanic events, the Oshetna tephra has multiple glass compositions and therefore it is unclear whether this tephra represents an eruption with a heterogeneous composition or multiple discrete tephrafalls compounded in the mSRV. Potential hiatuses in cultural occupation of the mSRV occur following deposition of these tephras, but characteristics of archaeological assemblages in the mSRV are in accordance with general

transitions in central interior Alaskan archaeology. Information from other volcanic events suggests that tephra deposition in the middle Susitna River Valley would have affected resource procurement in the area and therefore likely contributed to cultural hiatuses, especially following deposition of the Watana tephra. This project has clarified the Holocene stratigraphic sequence of the middle Susitna River valley, Alaska, and provided a more complete context for interpretation of the archaeological record.

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Chapter 1: Introduction

When a volcano erupts explosively, it can result in the dispersal and deposition of fine volcanic particles hundreds to thousands of kilometers from the source vent. Because fallout of volcanic ash is a temporally restricted event, the deposit forms a unique isochron that can be used as an interdisciplinary tool for correlation and chronologies (Kuehn et al. 2011). In areas such as interior Alaska and the Alaska Peninsula, which may be affected by ashfall from Aleutian Arc Volcanoes, tephrochronology is an important multi-disciplinary tool that can contribute to a comprehensive understanding of the processes that have affected an area through time. Refining tephrochronologies helps clarify eruptive histories of volcanoes and allows for evaluation of the potential effects of tephra deposition on the landscape, which has important implications for prehistoric use of an area by hunter-gatherers.

In the middle Susitna River Valley (mSRV), central Alaska, multiple tephra layers indicate that volcanism affected the area repeatedly during the Holocene epoch, with archaeological work revealing that hunter-gatherers utilized the area over the past 10,000 years, both before and after several significant volcanic events (Dixon et al. 1985; Dixon 1999; Wygal and Goebel 2012). Although archaeological investigations in the mSRV have revealed several tephra layers in the stratigraphy, problems with the radiocarbon chronology have complicated a comprehensive understanding of when prehistoric populations were utilizing the area relative to the timing of volcanic events. In addition, there has been little formal consideration of how volcanic events may have affected hunter-gatherer subsistence strategies. This study incorporates tephra and archaeological analyses in order to clarify the history of volcanic ash deposition in the mSRV during the Holocene and evaluate the potential impacts of ash deposition on prehistoric populations in the area.

1.1 Tephra and tephra analysis

Tephra is a term describing products of an explosive volcanic eruption, which travel through the air before being deposited (Thorarinsson 1974). Tephra particles may vary in density and size, from ash (< 2 mm) to bombs (> 64 mm), and may be comprised of three components: volcanic glass, mineral crystals and fragments thereof (which may or may not be juvenile), and lithic material (Alloway 2007; Sarna-Wojcicki 2000). Lithic fragments (and minerals that may be contained within them) are older, pre-existing materials that become entrained during the eruption whereas juvenile portions of tephra, which include volcanic glass and minerals, form during the eruption (Kittleman 1979). The volcanic glass fractions of tephra represent the composition of the magma at the time of the eruption, and may have unique compositions that allow them to be correlated.

The area of tephra deposition depends on factors such as the size and type of the eruption as well as wind directions and speeds. The size, thickness, and volume of the volcanic deposit generally decreases with distance from the source, resulting in a wedge-shaped deposit that is thickest proximal (closest) to the source and thins as it becomes more and more distal (farther from the source) (Alloway 2007; Kittleman 1979; Thorarinsson 1979). Tephra may be distributed in a variety of patterns, ranging from circular distributions surrounding the volcanic vent, which is typical for lower eruption columns occurring at times with little wind, to elliptical and fan-shaped patterns typical of higher eruption columns and directional wind, with the vent located at the apex of the distribution (Alloway 2007). Shifting wind patterns and very high eruption columns entering different levels of the atmosphere may result in overlapping and complicated tephra depositional trajectories (Alloway 2007; Kittleman 1979).

Tephrochronology, originally defined as a chronology based on measuring, connecting and dating tephra layers, also now describes a relatively recent discipline that is concerned with the study of tephra for correlation and dating purposes (Sarna-Wojcicki and Davis 1991). The discipline operates under two premises: 1) that tephra units have physical and chemical characteristics which allow them to be distinguished regardless of the mode of transportation or depositional history, and 2) that correlatable tephra from the same eruption were transported and deposited over a short time period (Sarna-Wojcicki 2000). Tephrochronology includes two subdisciplines: 1) tephrostratigraphy, which refers to the correlation of tephra based on physical and chemical characteristics, and 2) tephrochronometry, which refers to dating tephra layers either directly via techniques such as potassium-argon, or indirectly using associated layers and radiocarbon dates (Sarna-Wojcicki and Davis 1991). Tephrochronology draws on both sub-disciplines to comprehensively characterize and date a tephra layer, thereby allowing it to be utilized as a multi-disciplinary tool.

Correlation of a tephra layer over a large geographic area requires comprehensive field and geochemical characterization. Field characterization includes information on the physical continuity and characteristics of the bed, such as upper and lower contacts, thickness, grain size, texture, grading, minerals, lithic fragments, color, grittiness, weathering, and stratigraphic context (Sarna-Wojcicki 2000). In areas such as Alaska, field characterization is made difficult by the presence of numerous tephra beds within one region (from many source vents), as well as multiple tephras erupted from the same volcano. What may appear as one tephra bed could in fact be multiple tephras that have been reworked or compounded and only appear to represent a single, discrete event.

Despite magmatic processes leading up to a single eruption being complex, it is widely assumed that the geochemistry of the glass component (compared to the bulk composition) of a tephra is unique, relatively homogenous, and can be correlated in proximal, intermediate, and distal deposits (Kuehn et al. 2011; Lowe 2011; Sarna-Wojcicki and Davis 1991). Although not always possible, major-oxide glass geochemistry may be used to distinguish between eruptions from the same volcanic source vent. Analysis of individual glass shards also allows for identification of minor secondary compositions within a deposit that can be used for correlation purposes; minor secondary glass compositions may be unique to that eruption as a result from magma mingling or unique to the eruptive source. Multiple glass populations may also result from contamination by multiple overlapping deposits. Because tephrochronology or the use of tephra beds as isochronous horizons relies on the ability to distinguish, identify, and correlate individual tephra beds, it requires a precise and accurate method of geochemical analysis. As a grain-discrete method of analysis, electron probe microanalysis (EPMA) is ideal because it allows geochemical data to be collected from small particles. Comprehensive tephra characterization may provide indications as to the source volcanic vent that produced the tephra, either through the presence of characteristic minerals, unique glass geochemistry, or correlation to previously characterized tephra with established, known sources.

Generally, tephra deposits have three appealing characteristics for multi-disciplinary use: tephra deposits may cover a large area, are intruded upon the landscape regardless of what the landscape is, and form over a relatively short amount of time (Kittleman 1979). These characteristics may allow a tephra bed to be correlated across large geographical space and offer utility as an isochron that may be used for relative dating purposes (Lowe 2011; Sarna-Wojcicki 2000). A tephra bed correlated over a large area is an isochron, in that it effectively represents an instant in time and has an identical age wherever it occurs; however, a sequence of volcanic eruptions over a specific length of time may produce a series of tephra deposits that are isochronous and represent the passage of time wherever they occur (Lowe 2011). Dugmore et al. (2000:181) clarifies, "each tephra layer marks a surface at a moment in time; multiple tephra layers constrain the passage of time."

1.2 Anthropological studies in volcanically active regions

Although it is a distinct discipline, tephra analysis is applied in multiple disciplines because of the utility of tephra layers as stratigraphic time-marker horizons. Anthropological studies in volcanically active areas have also had the goal of understanding how volcanic events, evidenced by tephra layers, impacted prehistoric human populations. Indeed, despite the fact that volcanic events may be instantaneous or short-lived events, historic explosive volcanic events have demonstrated the potential for long-term environmental and ecological consequences of tephra deposition. Three often cited cultural consequences of major volcanic eruptions are local population extinction, site abandonment and migration (potentially with later replacement populations), and modifications in behavior following an eruption. Modifications in behavior may be indicated by changes in material culture or evidence of intensified regional relationships contemporaneous with or subsequent to the volcanic event (Cashman and Giordano 2008; Dumond 2011; Workman 1979).

Volcanic hazards vary depending on the type of volcanic processes occurring, as well as proximity to populations and associated infrastructure. In Alaska, volcanic activity occurs as a result of convergence and subduction of the Pacific Plate beneath the North American Plate, which generates melting in the upper mantle. This melt has a few characteristics that cause it to erupt explosively: high silica content, low temperature, and high volatile gas content (Lockwood and Hazlett 2010). Magmas with high silica contents are more viscous and likely to retain volatiles in solution; however, if pressure within the magma chamber decreases, gases (typically water and carbon dioxide) come out of solution, expanding rapidly and causing the magma to fragment explosively, often resulting in deposits such as tephra layers (Lockwood and Hazlett 2010).

In Alaska, volcanism is recognized as having potentially affected prehistoric populations, especially in the very volcanically active Aleutian Arc. Black (1981), for example, postulates that volcanic eruptions served to decrease population sizes, as both submarine and subaerial eruptions could have adversely affected marine and terrestrial resources. As the base of local hunter-gatherer subsistence, any adverse effect resulting from a volcanic eruption would have made survival difficult, even on timescales as short as a few years. However, Workman (1979) suggests that localized disasters, such as volcanic eruptions in the eastern Aleutians, would have had little long-lasting cultural impacts because the populations were abundant and widespread geographically during the timeframe of the larger eruptions in the Aleutians.

Dumond's (1979, 2004, 2011) work on the relationship between multiple tephra units and archaeology on the upper Alaska Peninsula has likewise seen an evolution in contrasting ideas on the effects of volcanic eruptions in the Naknek River drainage. Using the 1912 eruption of Katmai as an analog, Dumond (1979) determined that only one of nine tephra depositional events likely had an effect on the local population, causing local abandonment but no change in culture. However, two of the nine tephra occur at a boundary between different cultural traditions. Later, Dumond (2004, 2011) incorporated additional work in volcanic and cultural investigations and revised his conclusions, determining that at least three of the tephra deposits could have, in addition to other environmental factors, disrupted cultural occupations in the area and contributed to hiatuses and changes in cultural traditions.

Comprehensive analyses of the effects of volcanic eruptions on populations on the central Alaska Peninsula consider the stratigraphic context of a tephra as it relates to cultural occupations in the area, in addition to paleoenvironmental data. VanderHoek and Nelson (2007), for example, demonstrate that the caldera forming eruption of Aniakchak Volcano, approximately 3400 cal yr B.P. (calibrated years before present) likely occurred during a warm season, as indicated in wind patterns, peat clasts suggesting lack of snow cover, and evidence for the generation of a tsunami. In combination with local pollen data, a decrease in vegetation is indicated following the eruption, which likely reflects lower biological productivity; these patterns are interpreted as being related causatively to a hiatus in cultural occupations occurring from 3400–2100 cal yr B.P. Following the eruption, different cultural complexes appear, suggesting that one population was pushed out of the area or locally extirpated due to volcanic activity, while other areas experienced subsequent cultural amalgamation and change (VanderHoek 2009).

In addition to long-lasting imprints on the landscape, volcanic events may also leave long-lasting social and psychological effects that become ingrained in the ideologies of cultural groups (Cashman and Giordano 2008). Oral histories may conflate details and obscure geologic contexts, but they may also contain information regarding a volcanic event and the subsequent effects of it (Cashman and Giordano 2008). Workman (1979) considered the range of ecological responses to deposition of the east lobe of the White River Ash, between 1400 and 1200 cal yr B.P., which is widespread in eastern Alaska, Yukon Territory, and western Northwest Territories. He determined that the implications of tephra deposition for local hunter-gatherer groups were likely negative and encouraged outward migration from the ash fallout area. Moodie (1982) later interprets northern Athabascan origin myths as referencing the volcanic eruption that resulted in the widespread White River Ash east lobe, for multiple northern Athabascan myths refer to a mountain that speaks and then subsequently opens up and explodes, after which groups of people migrated and could no longer understand each other (Moodie 1982). Despite the myths being restricted to groups now living in at the eastern margins of the ash fallout zone, Moodie's (1992) interpretation is supported by linguistic evidence for diversion around that time and decreased frequencies of radiocarbon dates following White River Ash east lobe deposition (Mullen 2012). Oral traditions have also been demonstrated as encoding important information not only regarding disruptive volcanic events (Swanson 2008), but also in how to mitigate and survive them in light of resource crises (Minc 1986).

As demonstrated in the examples above, research into the effects of volcanic eruptions on prehistoric populations trend either towards the resilience of a population or adaptability. Research into disaster archaeology, which often includes volcanic events and their effects on human populations, has also emphasized understanding the vulnerability of a group, which is defined as the capacity of a group to anticipate, cope with, resist and recover from a natural hazard (Blaikie et al. 1994). However, in the absence of direct evidence of how a volcanic event affected a cultural group, such as the ash-encased remains and structures of Pompeii, stratigraphic and environmental data offer a means towards a more informed argument as to the effect that a volcanic eruption may have had on cultural groups within an area.

The presence of a tephra layer may not necessary equate with an environmentally catastrophic event, but considering the scale and frequency of the events as well as the potential for warning prior to the event may contribute to a better understanding of their impact on populations (Sheets and Grayson 1979; Torrence and Grattan 2002; VanderHoek and Nelson 2007). However, evidence of an association between tephra deposits and changes in archaeological context is not evidence that the volcanic events caused the change. The scale, magnitude, and nature of *both* volcanic and cultural deposits need to first be evaluated relative to the environmental context in order to reconstruct and understand the processes and mechanisms by which volcanic eruptions could have impacted people in an area (Shimoyama 2002; Torrence 2002). Cashman and Giordano (2008) note that investigations of the impact of volcanic events on past cultures can also contribute to modern volcanic hazard management and assessment of risk to contemporary populations living in similar areas.

1.3 Research objective and specific research questions

Volcanism in Alaska and its effect on past human populations is a particularly important research topic, especially given the high frequency of previous volcanic eruptions in Alaska and the potential for active volcanoes in the state to affect current populations. In the mSRV, an upland area on the fringe of marginality for several resources, there is evidence for use of the area by prehistoric hunter-gatherers throughout the stratigraphic record, both before and after periods of volcanic ash deposition; however, there is ambiguity regarding the number of ash depositional events and their timing and there has been little formal consideration as to how these volcanic events may have impacted prehistoric hunter-gatherers who utilized the area. The general objective of this study is to clarify the stratigraphic history of the mSRV and investigate how the deposition of tephra may have affected prehistoric hunter-gatherer use of the mSRV, in central interior Alaska. In addressing this broad objective, four specific research questions are investigated using different types of data.

1) How many volcanic events are represented in the stratigraphic record of the mSRV and what are their sources?

Investigations in the mSRV have identified three or four tephra units in the mSRV. Specifically, there is ambiguity regarding the middle tephra unit, which has been separated into an upper and lower component based on differences in color. Although Hayes Volcano has been the suggested source of the tephra in the mSRV, there has not been a formal attempt to correlate the tephra in the mSRV to the eight tephra layers recorded proximal to Hayes Volcano. Therefore, addressing this research question requires consideration of both field and geochemical characterization of tephra from the mSRV, a distal environment, and proximal tephra from the suggested source, Hayes Volcano. Consideration of characteristics of both distal and proximal

Hayes Volcano tephra allows for a direct attempt at correlation and aids in understanding the stratigraphy of the mSRV.

2) When were prehistoric hunter-gatherers using the mSRV and how does the timing of cultural occupations relate to the timing of tephra depositions?

Many cultural occupations in the mSRV have previously been dated; however, there are problems associated with some these dates, which include large standard deviations and dating of bulk charcoal samples. As part of this study, cultural occupations and stratigraphic positions in the mSRV are dated and evaluated relative to existing dates in an effort to better evaluate the timing of tephra deposition and timing and continuity of cultural occupations; i.e. is cultural occupation in the area continuous or segmented with hiatus periods occurring following volcanic eruptions, and if so, how long do the hiatuses last?

Hayes Volcano tephra have been identified at many locations in the Cook Inlet area as part of archaeological, geological, and environmental investigations. As such, numerous radiocarbon dates have been produced and provide maximum or minimum age limitations. Independently, these dates provide isolated estimations of tephra depositional age; however, collectively, the dates aid in modeling the timing of deposition of individual tephra units in the mSRV, which provides the context necessary for interpreting the archaeological record.

3) What can information on other volcanic eruptions and ash depositional events tell us about the potential effects of ash deposition on the environment of the mSRV and what are the implications for hunter-gatherer resource procurement?

There have been numerous explosive volcanic eruptions in the past century that have resulted in ash deposition in both proximal and distal environments. The effects of ash deposition on plants and animals have been documented closely in some cases, with respect to the amount of ash deposited, the type of plants affected by ash deposition, the rates of plant recovery, and direct effects on people and animals. In conjunction with studies on successional processes in Alaska, these events can inform a qualitative model of the potential effects of ash deposition on plants and animals in the mSRV, that has important implications for considering how tephra deposition may have affected hunter-gatherer resources.

Archaeological investigations have revealed that the mSRV was occupied intermittently over the past 10,000 years (Dixon et al. 1985; Dixon 1999; Wygal and Goebel 2012); tephra were deposited in the mSRV during this time and likely would have affected hunter-gatherer resource acquisition in the mSRV. Ethnographic data on Athabascan groups that utilized the mSRV historically provides information on specific resources that were acquired in the mSRV and when they were being acquired. In conjunction with archaeological data on subsistence systems through time and information on the effects of tephra deposition on the environment, this information contributes to a model of the effects of tephra deposition on the mSRV environment, with particular attention to hunter-gatherer resource acquisition and behaviors. The theoretical framework of human behavioral ecology is employed to aid in evaluation.

4) Are there significant differences in archaeological components bounded by tephra units in the mSRV and how do cultural occupations in the area relate to our understanding of interior Alaskan archaeology?

This question relies on consideration of archaeological assemblage characteristics in the mSRV, and incorporates information on established transitions in archaeological assemblages through time in central interior Alaska. The stratigraphy of the mSRV allows for archaeological components to be grouped by stratigraphic position, offering a unique means to evaluate characteristics of archaeological sites bounded by tephra units. Hiatuses in cultural occupations in the mSRV, indicated by a lack of radiocarbon dates from cultural components, are also evaluated related to established changes in material culture and subsistence and settlement patterns through time in interior Alaska in an effort to understand the implications of ash deposition on these different settlement and subsistence systems.

1.4 Thesis organization

This thesis is organized into six chapters. Chapter Two provides background information relevant to the study. The materials and methods, as well as theoretical approach, are outlined in Chapter Three. Chapter Four presents the results of analyses done as part of this research, which include tephra, radiocarbon, and archaeological analyses. Chapter Five discusses historic volcanic events and their environmental consequences, as well ethnographic data on hunter-gatherer exploitation of the mSRV as a means to model the potential effects of tephra deposition in the mSRV with respect to subsistence resources. Chapter Six synthesizes the model of ash deposition in the mSRV and results of analyses relative to the objective of this project and specific research questions. Chapter Seven presents directions for future research and summarizes the results and conclusions of this study.

Chapter 2: Background

This chapter will introduce background information relevant to this study. The chapter is separated into four sections: Section 2.1 describes the study area; Section 2.2 summarizes the mSRV stratigraphy and previous tephra correlations; Section 2.3 details the history of archaeological investigations in the mSRV, in relation to the archaeology of the region; and, Section 2.4 outlines the problems prohibiting a comprehensive understanding of the mSRV stratigraphy and archaeology, which this study has the goals of addressing.

2.1 Study area

The area of study encompasses the Cook Inlet region of Alaska, much of which is a remnant of a Tertiary-age sedimentary basin. The basin is bounded by terranes that accreted in the Mesozoic and Cenozoic, and the Alaska-Aleutian Range batholith. Volcanic products originating from the modern Aleutian arc are also present (Wilson et al. 2009). Mountainous and high relief areas border the Cook Inlet; however, lower relief characterizes the riverine areas. The region is bounded by the Aleutian Range to the southwest, the Alaska Range to the north, the Talkeetna Mountains to the south, and the Chugach Mountains to the east. Metamorphic, volcanic, and sedimentary rocks constitute a complex substrate in the Cook Inlet and in the mSRV, the bedrock is comprised of thinly bedded Mesozoic phyllite with vugs and veins of quartz which has been scoured and overlain by Quaternary glacial and periglacial processes and deposits (Csejtey Jr. 1976; Gallant et al. 1995; Gilman et al. 2009; Kachadoorian 1974).

As a result of the mountainous and high relief areas bordering the Cook Inlet, it is an outlet for numerous rivers, the two largest of which are the Susitna River and the Matanuska River. These rivers alternate between braided and silt-laden to flowing through and cutting into steeply walled canyons and gorges. The Susitna River originates at the Susitna Glacier in the eastern portion of the Alaska Range and flows southwest 500 km until empyting into the Cook Inlet, west of Anchorage and the Cook Inlet's Knik Arm (Helm and Collins 1997). The mSRV encompasses the section of the river approximately 200 km north of Anchorage and 280 km south of Fairbanks, which flows sinuously in a generally east to west direction before turning south towards Cook Inlet (Kachadoorian 1974) (Figure 2.1).

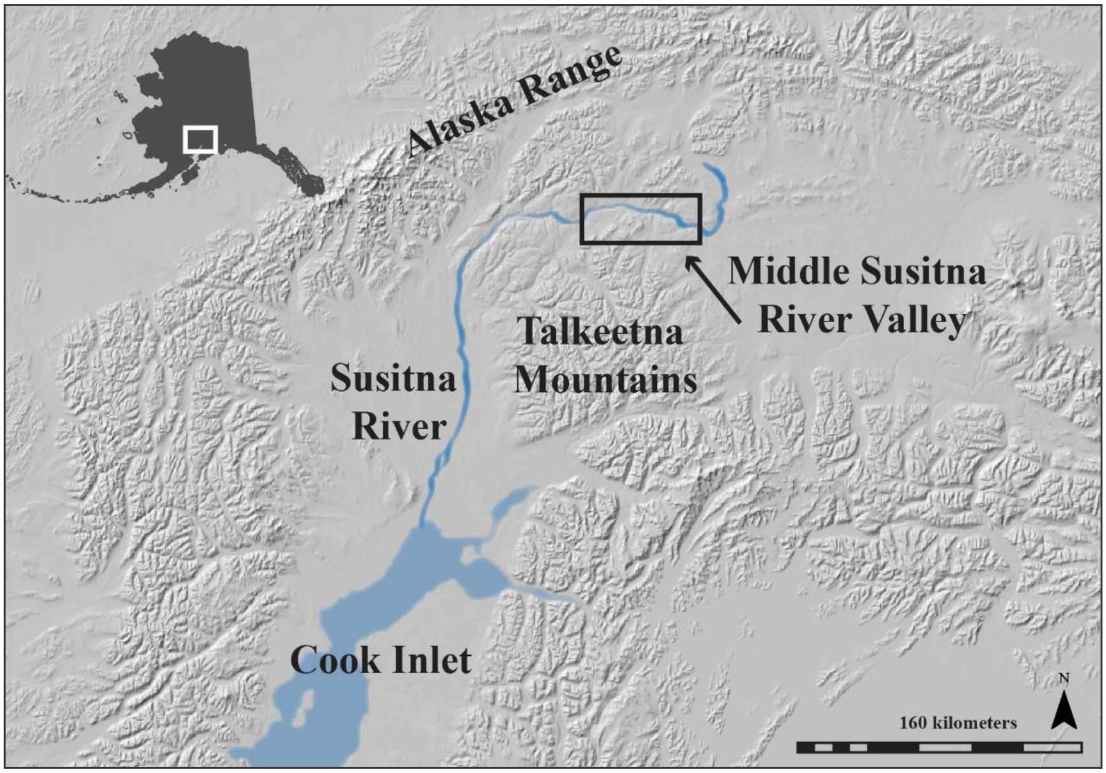


Figure 2.1. Location of the middle Susitna River Valley (mSRV), Alaska. Mountainous terrain surrounds the study area.

2.1.1 Physiography

The Gulf of Alaska has a complicated glacial history; it was heavily glaciated during the last Quaternary Pleistocene glaciation and its present geomorphology is largely a reflection of that and its tectonic history. Evidence for at least three major glaciations in the Pleistocene are present in the area: an Illinoian glaciation evidenced by high elevation drift, colluviated drift, and ice-stagnation deposits; a less extensive early Wisconsin glaciation indicated by radiocarbon data and evidence for an ice- or moraine-dammed lake; and, lastly, a late Wisconsin glaciation that imprinted the general area with a complex mosaic of crosscutting ground moraines, drumlin fields, eskers and outwash plains that contribute to a gently rolling terrain characterized by swamps, bogs, and small lakes (Gallant et al. 1995; Reger et al. 1995). Deglaciation of the Susitna River Valley occurred roughly 12,000 to 14,000 cal yr B.P. (Bigelow et al. 2015).

Whereas glaciation and glacial retreat scoured bedrock and imprinted the area with hummocky kame and esker deposits, stream incision during the Holocene has resulted in terraces and bluffs along the Susitna River and its tributaries (Dilley 1988). Tributaries to the Susitna River, originating from Holocene-aged glaciers that have not extended beyond alpine valleys, include the Oshetna River and Watana, Jay, Deadman, Tsusena, Kosina, and Fog Creeks; lakes are also present in valley, including Butte, Big, Stephan, Clarence, and Fog Lakes (Bigelow et al. 2015; Reger et al. 1990).

In the mSRV, tall and steep mountain slopes that range from 5–25 degrees meet broad valleys that are on average 600 m above sea level (Gallant et al. 1995) (Figure 2.2). Alluvial, aeolian, glacial, and periglacial processes drive the geomorphology of the mSRV; surrounding the river is Holocene-aged alluvium composed of gravels and sands, often as terraces or small alluvial fans (Wilson et al. 2009). As a result of re-working, alluvium thickness is variable, but has a maximum thickness of 10 m in some areas (Wilson et al. 2009). Lacustrine deposits in the area are generally composed of silt, clay, and fine sand that are derived from glaciolacustrine lakes, and gyttia (organic-rich sediment) from deeper lakes; peat is found in wetlands and bogs and is underlain by permafrost.

Figure 2.2. View of the Susitna River and surrounding landscape. Photo taken at junction of Denali Highway and the Susitna River, taken by the author.

2.1.2 Paleoenvironment

Paleoenvironmental reconstructions of interior Alaska have documented shifts in vegetation, climate, and general ecology extending into the late Pleistocene. These changes have been investigated through the use of proxy data, such as palynological and plant macrofossil data from lacustrine and peat cores, and faunal data from archaeological sites. These records will be briefly summarized for a glimpse of changes in ecology through time in central interior Alaska. All dates are reported in calibrated radiocarbon years before present (cal yr B.P.).

Pollen and plant macrofossil analyses indicate that interior Alaska experienced several general transitions in vegetation characteristics during the Holocene, the timing of which varied slightly depending on location. Generally, a Pleistocene Late Glacial Maximum (LGM) herb tundra-dominated landscape shifted to shrub-tundra approximately 14,000 cal yr B.P., with more woody populations, especially birch, dominating the landscape (Ager 1983; Anderson et al. 2004; Bigelow and Powers 2001). The initial transition from herbaceous to shrub dominated tundra prior to the Holocene is associated with a shift in climate from the LGM, which was cold and arid with lower lake levels, to a warm and mesic climate with greater summer precipitation, higher lake levels (closer to modern levels), and greater snow depths (Ager 1983). These conditions of warmer than modern summers and colder than modern winters are associated with some of the earliest archaeological sites in Alaska (Ager 1983; Anderson and Brubaker 1994; Anderson et al. 2004; Bigelow and Edwards 2001; Bigelow and Powers 2001). Beginning around 12,800 cal yr B.P., some areas of Alaska were affected to various extents by the Younger Dryas cooling event, with areas south of the Alaska Range experiencing cooler summers and greater snow during winter (Bigelow and Powers 2011; Graf and Bigelow 2011).

In the early Holocene, the Holocene Thermal Maximum (HTM) (11,000–9,000 cal yr B.P.) is associated with the shrub-tundra vegetation being replaced by deciduous scrub-forest. Initially, *Populus*, likely balsam poplar and quaking aspen, and various willow (*Salix*) species appeared, followed by *Picea*, such as black spruce and white spruce by 10,200 cal yr B.P. (Ager 1983; Anderson and Brubaker 1994; Mason and Bigelow 2008). During the HTM, greater summer and winter solar insolation caused more extreme seasonal temperature variations (Bigelow and Powers 2001; Kaufman et al. 2004). At Deadman Lake, at 960 m elevation in the Susitna River Valley, spruce pollen rises as early as 9500 cal yr B.P., which pre-dates spruce pollen rises at lower elevation lakes in the area and suggests that spruce originated in the east

(Bigelow et al. 2015). White spruce decrease between 9000 and 7800 cal yr B.P. during the Hypsithermal, a period of warmer and drier climate that was followed by an increase in moisture and decrease in summer temperatures that resulted in paludification (formation of peatlands), and expansion of black spruce on the landscape (Ager 1983; Anderson et al. 2004). Indeed, Alder (*Alnus*) species appear around 8400 cal yr B.P. and shortly thereafter, from 7800–6800 cal yr B.P., both species of spruce expand, but black spruce dominates the landscape (Ager 1983; Mason and Bigelow 2008).

These successive invasions of forest species transformed the landscape into a "mosaic of forests, muskegs, tundra, and forest tundra" that exhibited altitudinal zonation (Ager 1983:139). Between 6000 and 4000 cal yr B.P., interior Alaska had developed vegetation characteristics similar to that of the modern boreal forest and tundra; however, the distributions likely did not resemble that of the present day until much later (Anderson and Brubaker 1994; Mason and Bigelow 2008). Notably, pollen from high elevation lakes (Deadman and Clarence) in the Susitna River Valley indicate a decrease in spruce pollen after 4500 cal yr B.P. (Bigelow et al. 2015), possibly associated with mid-Holocene Neoglacial glacial expansion from 5000–4000 cal yr B.P.

Lacustrine cores from Swampbuggy and Nutella Lakes, at treeline in the central Alaskan Range, record climate variations closer to the mSRV for approximately the past 7600 cal yr B.P. (Rohr 2001). Stable carbon and nitrogen isotopes, pollen, macrofossils, and loss-on-ignition (LOI) analyses indicate that from approximately 7600–5700 cal yr B.P., the climate was warm with increasing moisture and decreasing temperatures towards the Neoglacial. During the Neoglacial, lower lake productivities suggest a cooler and moister climate until about 1400 cal yr B.P. (Rohr 2001). Indeed, lower spruce counts at Deadman and Clarence Lakes after 4500 cal yr B.P. also suggest reduced spruce abundances at high elevation due to cooler summer temperatures associated with Neoglacial (Bigelow et al. 2015). However, following this is a warmer, more arid interval indicated by higher relative lake productivity and decreasing frequencies of both spruce species until roughly 700 cal yr B.P. (Rohr 2001). Wendt (2013) postulates that climate variations definitely affected ecosystems in the mSRV, and therefore affected resource availability; at Butte Lake site, cultural components occur during periods of relatively high effective moisture, which Wendt (2013) relates to the development of suitable terrestrial biomes and associated resources, making the area attractive to hunter-gatherers.

Mason and Bigelow (2008) note that early to mid-Holocene landscape and vegetation responses to climate events were complex and Guthrie (2006:207) attributes the extinction of mammoth and horse in North America to the "drastic ecological restructuring" that took place at the transition from the Pleistocene to the Holocene. Contrarily, wapiti and moose appear coincident with bison expansion at the same time as major shifts in vegetation at the Pleistocene-Holocene transition, particularly the expansion of willow (Guthrie 2006). Wapiti persist until the mid-Holocene in Alaska, bison until roughly 200 cal yr B.P., and moose have been present continuously until present day (Guthrie 2006; Stephenson et al. 2001).

2.1.3 Modern climate and ecology

The mSRV is part of the Alaska Range ecoregion, which is predominantly a mountainous upland region with unique features dictating where faunal and floral resources are available on the landscape (Gallant et al. 1995). The Alaska Range ecoregion is characterized less by vegetation and more by rocky slopes, ice fields, and glaciers. The climate is continental, with high precipitation rates of 2030 mm in the peak zones, and lower precipitation rates of 380 mm in the valley lowlands (Gallant et al. 1995). Temperatures range from -25 in the winter to 18 degrees Celsius in the summer (Gallant et al. 1995). High slopes facilitate erosion and prevent extensive deposition and soil formation.

In the Alaska Range ecoregion, high slopes also inhibit the growth of later successional species such as spruce; however, well-drained high slope areas with soil do support dwarf scrub species if windswept, which include mountain avens (*Dryas octopetala*), sedges (*carex* spp.), grasses (graminoids), and lichens. If protected, well-drained areas will support low or tall scrub communities such as birch, bog blueberry (*Vaccinium uliginosum* L.), herbs, willow, and alder. Well-drained valleys and lower elevation hill-slopes support needleleaf forests and woodlands with populations of white spruce, black spruce, and low woody species including highbush cranberry, crowberry (*Empetrum nigrum)*, red-fruit bearberry (*Arctostaphylos rubra*), and mountain avens underlain by mosses and lichens (Gallant et al. 1995). Areas of similar elevation and vegetation characteristics nearby in the Little Susitna River Valley reported rapid green growth around June 1 every year, with the first frosts occurring around September 10, followed by rapid vegetation death (Hock and Cottini 1966).

Faunal presence and abundance in the mSRV is driven by the availability of resources. Black bears frequent lower elevation areas during spring and summer, feeding primarily on berries; grizzly bears are less frequent than black bears, and eat berries, horsetail, and sometimes moose calves (Alaska Energy Authority 2012a; Hock and Cottini 1966). Ptarmigan are present in spring and fall, relying on willow for sustenance (Alaska Department of Fish and Game 2015; Alaska Energy Authority 2012a). Hoary marmot, red squirrel, arctic ground squirrel, collared pika (rock rabbit), various voles, mice, and shrews are seasonally present during warmer months (May to September) and the porcupine is present all year (Alaska Energy Authority 2012a).

Dall sheep are present in the mSRV, and frequent the Jay Creek and Watana Creek mineral licks between mid-May and mid-June (Alaska Energy Authority 2012a). Wolves and wolverines utilize high elevation areas more often during summer months due to the availability of caribou. Caribou, presently the Nelchina and Delta Herds, utilize areas of the Susitna River Valley during the summer and winter; during warm weather they eat willow leaves, sedges, flowering tundra plants, and mushrooms, whereas in fall and winter they rely on lichens, sedges, and shrubs (Alaska Department of Fish and Game 2015; Alaska Energy Authority 2012a). Moose are noted predominantly in fall and winter, but may occur occasionally in summer months; during the fall and winter they rely on willow, birch, and aspen twigs whereas in summer they subsist on forbs, vegetation in shallow ponds, and birch, willow, and aspen leaves (Alaska Department of Fish and Game 2015; Alaska Energy Authority 2012a).

2.2 Middle Susitna River Valley stratigraphy

The stratigraphy of the mSRV varies from areas of exposed bedrock scoured by glaciers to areas with 1.5 m of fluvial and eolian sediment accumulation. Much work has been devoted to understanding the timing and development of the generalized regional stratigraphic sequence, with special attention to the soils (Dilley 1988) and tephra of the mSRV (Dilley 1988; Dixon et al. 1985; Dixon and Smith 1990; Romick and Thorson 1983). During investigations for the Susitna Watana Hydroelectric Project in the 1980s, soils and sediments from terrestrial sections and materials from lacustrine deposits and a bog core were radiometrically dated; materials submitted for dating include charcoal, bulk charcoal, bulk peat, charred peat, bulk sediment, bulk organics, and bone (Dixon et al. 1985). Although there are problems associated with many of these original dates (discussed in Section 2.4), the general stratigraphic sequence derived from them is presented below. All radiocarbon dates are given as the calibrated to 2 σ range (calibrated using the IntCal13 terrestrial calibration curve in the CALIB Program, version 7.1; Reimer et al. 2013; Stuiver and Reimer 1993), with the raw radiocarbon age provided in parentheses.

2.2.1 General stratigraphy

The generalized regional stratigraphic sequence of the mSRV is composed of six major units and 10 subunits for a total of 16 stratigraphic units (Dixon et al. 1985). Elevations above 1500 m and slopes greater than 15 degrees have minor amounts of accumulated sediment, especially if windswept, and Romick and Thorson (1983) note that despite varied geomorphic and environmental settings, archaeological sites in the mSRV share generalized stratigraphic traits. Scoured bedrock is overlain by weathered glacial material, which is overlain by interbedded and informally named tephra deposits, paleosols, and eolian units (Dilley 1988; Dixon et al. 1985). The six major units present in the stratigraphy of the mSRV are (from base up): glacial drift, Oshetna tephra, unoxidized Watana tephra, oxidized Watana tephra, Devil tephra, and organic accumulations (Figure 2.3 and 2.4). This sequence represents distinct regional episodes of deposition, with discontinuous subunits between contacts of the major units (Dixon et al. 1985). Major units, subunits and associated dates and interpretations will be described below. Note, however, that this section summarizes the chronological framework for the mSRV derived from dates obtained during the 1980s, and significant revisions to this framework are established as part of this study (results are presented in Section 4.2.2 and discussed relative to the previously established mSRV chronology in Section 6.1.2).

Basal radiocarbon dates from work done in the 1980s indicate that glacial retreat in the Susitna River Valley occurred around 11,000 cal yr B.P. (Dixon et al. 1985); however, more recent dating efforts indicate it likely occurred earlier, between 12,000–14,000 cal yr B.P. (Bigelow et al. 2015). Glacially scoured bedrock is overlain by glaciofluvial, glaciolacustrine, or glacial drift that ranges from a few centimeters to greater than 1 m in thickness, with grain sizes ranging from sand to gravel (Dixon et al. 1985). Evidence for weathering and deflation occurs discontinuously over glacial drift in the mSRV, in the form of shallow oxidation and wind-polished rocks, or as eolian sand and/or silt (loess), sometimes with paleosols occurring within. Dilley (1988) dates these discontinuous entisols and inceptisols as being developed between

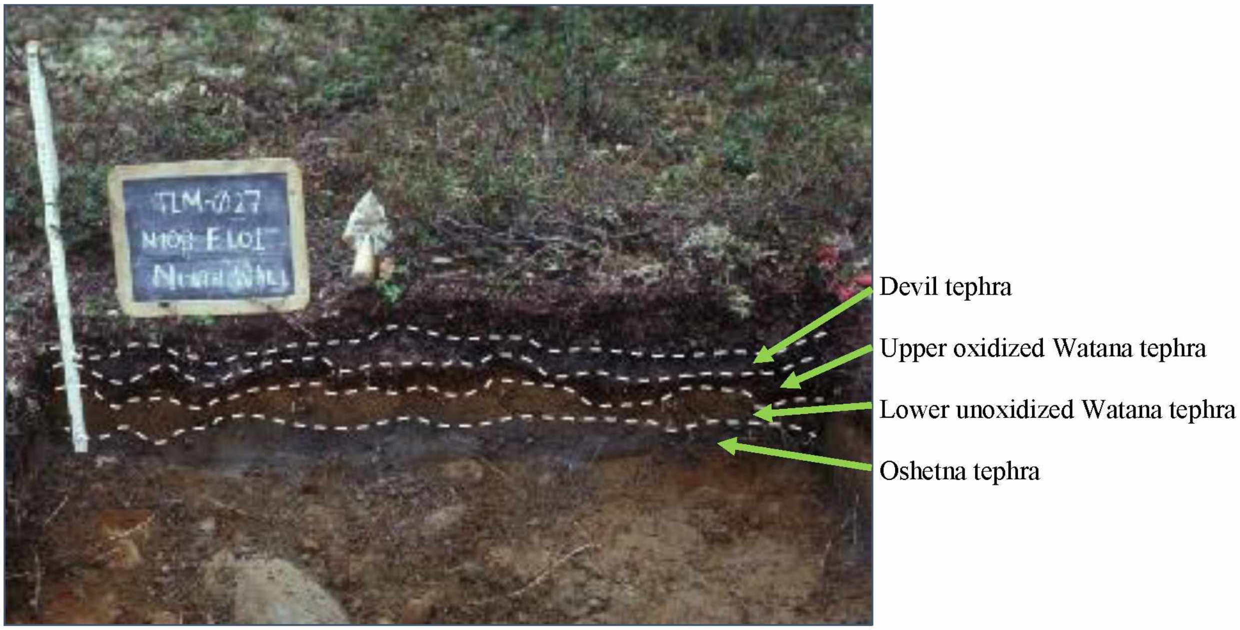


Figure 2.3. Stratigraphy at site TLM-027. Generalized stratigraphic characteristics of the mSRV displayed in the north wall of excavation unit N108/E101 at archaeological site TLM-027 (UAMN 1981). Unofficially named mSRV tephra are annotated.

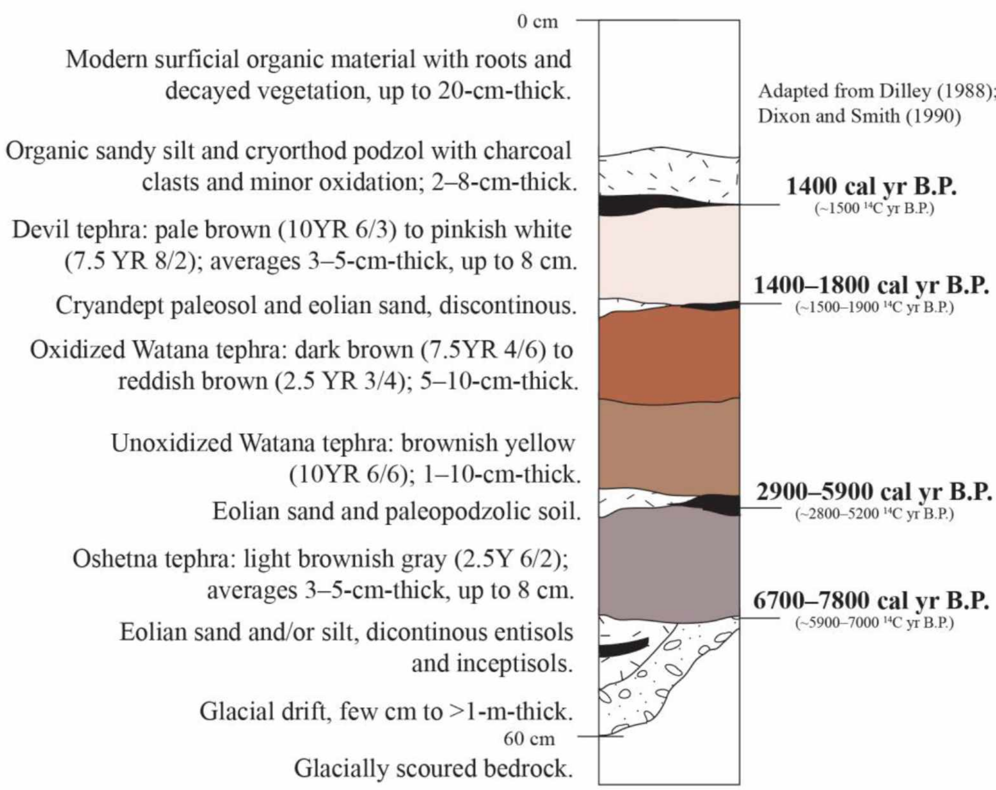


Figure 2.4. Generalized stratigraphy of the mSRV. Characteristics of the terrestrial stratigraphic sequence within the mSRV and associated calibrated age ranges produced during the 1980s, with raw radiocarbon date ranges provided in parentheses.

roughly 6700–7900 cal yr B.P. (5900–7000 ^{14}C yr B.P.). More recent dating of a paleosol at this location at Jay Creek Ridge archaeological site, however, indicates paleosol development between 11,200–11,250 cal yr B.P. (9790±60 ^{14}C yr B.P.; Beta-147295; UAMN 2015). This suggests that Dilley's (1988) originally dating scheme needs revising or that his analysis did not consider additional older paleosols within eolian deposits below the Oshetna tephra.

The Oshetna tephra occurs over, and sometimes mixed with the subunits below, as a light brownish gray (2.5Y 6/2) ash that is on average 3–5-cm-thick, with a maximum thickness of around 8 cm. Dates from the 1980s bracketing the Oshetna tephra indicated that it was deposited between 5900–6700 cal yr B.P. (~5200–5900 ^{14}C yr B.P.; Dilley 1988; Dixon et al. 1985; Dixon and Smith 1990; Romick and Thorson 1983). Above the Oshetna tephra are subunits that suggest both deposition and erosion, in the form of thin lenses of eolian sand, charcoal flecks, and a subunit of buried podzolic soil that is the dominant paleosol in the study area (Dilley 1988). Dilley's (1988) work, which considered dates produced during the 1980s, showed that this paleopodzolic soil was on the surface and developing for approximately 2400 years (2800–5000 ^{14}C yr B.P.), prior to the deposition of the next major unit above the Oshetna tephra: the unoxidized Watana tephra.

The unoxidized Watana tephra is brownish-yellow (10YR 6/6) in color and ranges in thickness from 1–10 cm. The unoxidized Watana is usually directly overlain by another of tephra unit, the 5–10-cm-thick oxidized Watana tephra, which is dark brown (7.5 YR4/6) to reddish brown (2.5 YR 3/4) in color, suggesting that it is strongly oxidized, possibly as a result of weathering. However, Dixon et al. (1985) note that the relationship between the unoxidized and oxidized Watana tephras sometimes appears gradational. Dates from the 1980s indicated that both the unoxidized and the oxidized Watana tephras were emplaced between 1800–2900 cal yr B.P. (1850–2700 ^{14}C yr B.P.) (Dixon and Smith 1990; Dixon et al. 1985; Romick and Thorson 1983). A rare subunit is noted between the unoxidized and oxidized Watana tephras, in the form of poorly developed and discontinuous thin eolian units or paleosols with charcoal (Dilley 1988). Textural and color differences, in addition to the sparse subunit (recorded at six localities) suggest that the two Watana tephras could represent at least two different depositional events that occurred in rapid succession (Dixon et al. 1985).

The oxidized Watana tephra is more weathered in its upper portion, suggesting a period of erosion and weathering at some point after deposition; it also contains sand-sized concretions, and sometimes appears as a durable cemented layer (Dilley 1988; Dixon et al. 1985). Above the oxidized Watana tephra is a buried discontinuous cryandept with charcoal and thin eolian sand, which produced a problematically young radiocarbon date of 400 cal yr B.P. (350 ^{14}C yr B.P.) in the 1980s, likely as a result of downward leaching of younger carbon (Dilley 1988). The more likely age range of the cryandept, based on dates produced during the 1980s, is 1400–1800 cal yr B.P. (1400–1850 ^{14}C yr B.P.; Dilley 1988; Dixon et al. 1985). The next major unit above is the Devil tephra, a pale brown (10YR 6/3) to pinkish white (7.5YR 8/2) 3–5-cm-thick tephra that is up to 8 cm thick in some areas (Dixon et al. 1985). The Devil tephra deposition was dated between approximately 1400–1800 cal yr B.P. (1500–1900 ^{14}C yr B.P.) during the 1980s (Dixon and Smith 1990).

Directly above the Devil tephra is cryorthod podzol that has developed within the last 1400 years, with some charcoal clasts and minor oxidation that extends 1–2 cm into the uppermost portions of the Devil tephra (Dilley 1988). The cryothod podzol consists of organic sandy silt 2–8 cm thick, capped by surficial organic material with roots and decayed vegetation up to 20 cm thick. Dixon et al. (1985) note that between the sandy silt and surficial organic material is a zone of decomposed macroscopic organic matter that likely reflects some change in sedimentation rate.

2.2.2 Tephra correlations

While initial field characterization of the tephras present in the mSRV suggested that three to four distinct volcanic events were represented, petrographic, mineralogic, and geochemical characterization and correlation of tephras in the area have attempted to determine the source and number of eruptive events represented in the terrestrial stratigraphy.

From an analysis of 31 samples from 11 sites spanning an area of 70 km, Romick and Thorson (1983) found that the mineralogy of the tephras in the mSRV are very similar, with comparable relative frequencies, grain size and shape distributions; however, the oldest tephra, the Oshetna tephra, has less glass shards. The characteristic presence of biotite in all tephra but the Oshetna tephra suggested Hayes Volcano as the source vent. Dixon et al. (1985) investigated the tephras present in the mSRV through mineralogic and petrographic analysis and investigations of glass shard morphology of 29 samples from 10 sites distributed across 48 km, to allow for better correlation and dating of archaeological components. Like Romick and

Thorson (1983), Dixon et al. (1985) found that the mineralogy of each of the tephras was quite uniform, with biotite suggesting Hayes Volcano as the source vent. In all analyses, the Oshetna tephra was concluded to be the only tephra distinguishable on the basis of mineralogy, with more plagioclase feldspar and quartz present, and an absence of biotite.

Romick's (1984) geochemical analysis of each of the tephra units in the mSRV (in Dilley 1988) demonstrates that the felsic volcanic glass portions of the unoxidized Watana, oxidized Watana, and Devil tephras are very similar in composition (Table 2.1), suggesting that the unoxidized and oxidized Watana tephras could represent multiple eruptions that took place within a narrow timeframe. This was supported by attempts at correlation to a lacustrine core from a kettle pond near Watana Creek, in the Susitna region, which exhibited evidence of six ashfalls over the past 6000 years (Dilley 1988). However, Dilley's (1988) attempts to correlate individual lacustrine tephra to terrestrial tephra (based on physical characteristics) were complicated by erroneous radiocarbon dates produced during the 1980s, with terrestrial radiocarbon dates indicated that Watana tephras were deposited after 2900 cal yr B.P. (2800 ^{14}C yr B.P.), while the lacustrine dates indicated that they were deposited prior to that. Dixon and Smith's (1990) later attempts to correlate the terrestrial tephra sequence with six tephra from (likely) the same pond core used by Dilley (1988) suggested that the Watana tephras in the terrestrial setting are in fact a set of four tephras; however, Dixon and Smith (1990), had similar issues in correlating these tephras as a result of date contradictions.

Table 2.1. Major-oxide glass compositions of mSRV tephra, from Romick (1984) in Dilley (1988).

Sample Name[a]	Unit[b]		SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	Cl	P_2O_5	$TOTAL_{raw}$	n
Not provided	Devil	mean	73.91	0.25	14.69	1.90	nr	0.51	2.17	3.70	2.52	0.34	nr	97.95	nr
		1 δ	*1.79*	*0.08*	*0.28*	*0.27*		*0.07*	*0.18*	*0.27*	*0.08*	*0.06*			
Not provided	Upper Watana	mean	74.34	0.19	14.77	2.20	nr	0.52	2.31	3.41	2.55	0.35	nr	96.57	nr
		1 δ	*1.22*	*0.05*	*0.41*	*0.36*		*0.16*	*0.27*	*0.20*	*0.07*	*0.06*			
Not provided	Lower Watana	mean	73.73	0.20	14.83	1.94	nr	0.50	2.26	3.64	2.55	0.35	nr	97.89	nr
		1 δ	*1.72*	*0.04*	*0.26*	*0.19*		*0.04*	*0.16*	*0.21*	*0.08*	*0.05*			
Not provided	Oshetna P-1	mean	63.81	0.89	15.54	6.52	nr	1.99	4.97	4.30	1.77	0.21	nr	96.87	nr
		1 δ	*2.31*	*0.12*	*0.26*	*1.12*		*0.37*	*0.61*	*0.09*	*0.32*	*0.04*			
Not provided	Oshetna P-2	mean	73.91	0.42	14.22	2.43	nr	0.54	2.18	3.65	2.43	0.21	nr	nr	nr
		1 δ	*2.61*	*0.09*	*0.91*	*0.42*		*0.15*	*0.33*	*0.41*	*0.25*	*0.05*			

[a]Dilley (1988) does not provide sample names or locations; [b]Unit refers to unofficially named tephras from the mSRV. No information on analytical routine or laboratory provided.

Reported compositions are weight percent averages of n points, normalized to 100 percent; total gives original sum, 1 σ is standard deviation, not standard deviation of the mean; nr is not reported; P-, population; raw, original raw total.

Dilley (1988) and Dixon and Smith's (1990) correlations are limited in that only one lacustrine core was sampled; however, terrestrial tephra characterization proximal to Hayes Volcano does suggest that more than one Hayes Volcano eruption could have deposited tephra in the mSRV (Riehle 1985, 1994; Riehle et al. 1990). Riehle (1985) characterized a Hayes Volcano tephra reference suite 55 km northeast of Hayes Volcano geochemically. At the reference section, Site 23 in the Hayes River Pass, the Hayes Volcano tephra set is comprised of seven to eight tephras. The tephras demonstrated chemical and mineralogical similarity, with a basal age of approximately 3750–4200 cal yr B.P. (3650±150 ^{14}C yr B.P.), older than terrestrial dates for the Watana tephra in the mSRV (Dilley 1988; Dixon et al. 1985; Dixon and Smith 1990; Romick and Thorson 1983). Riehle (1985) also noted another younger tephra layer attributed to Hayes Volcano, dated to between 400–1900 cal yr B.P. (525–1860 ^{14}C yr B.P.), and located at sampling Site 27. Riehle et al. (1990) estimated the south and northeast distribution of individual tephras within the Hayes tephra set and Riehle (1994) proposed Hayes Volcano tephra set be referred to as the Hayes tephra set H. Begét et al. (1991) later used a similarity coefficient to correlate distal tephras in other areas of central interior Alaska, more colloquially referred to as the Cantwell ash (Bowers 1979), Jarvis Creek Ash (Reger et al. 1964), and Tangle Lakes ash, to specific tephra units of the Hayes tephra set H from Riehle's (1985) Site 23. Distal samples were all very similar geochemically and were most similar to Riehle's (1985) Hayes Volcano proximal unit 23-G (Begét et al. 1991).

Tephra attributed to Hayes Volcano based on volcanic glass geochemistry have been noted in other areas of southcentral and central interior Alaska (Figures 2.5 and 2.6 provide reference locations and a summary of correlation efforts). A series of four or five terrestrial tephra from the Matanuska Valley were correlated to the Hayes tephra set H based on glass geochemistry, the presence of biotite, and similar age ranges; these tephra were also tentatively correlated to the mSRV lower unoxidized Watana tephra based on geochemistry (Fontana 1988). However, a total of nine tephra are noted in the Matanuska Valley, including a red-brown tephra older than 1900–2960 cal yr B.P. (2410±220 ^{14}C yr B.P.), and two tephra younger than that. Tephra found in cores from Wonder Lake in Denali National Park provide geochemical data (Table 2.2). Similar to Romick (1984, in Dilley 1988), Child et al. (1998) report two geochemical populations of volcanic glass in the Oshetna tephra. They also provide a maximum AMS (Accelerator Mass Spectrometry) date associated with one of the Hayes tephra depositions,

Table 2.2. Major-oxide glass compositions of tephra from Denali National Park and Preserve Wonder Lake area, from Child et al. (1998).

Sample Name[a]	Unit[b]		SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	Cl	P_2O_5	TOTAL $_{raw}$[c]	n
ACT 1082	Oshetna P-1	mean	72.54	0.49	14.35	2.31	nr	0.71	2.41	4.19	2.77	0.21	nr	95.16	17
		1 δ	*0.46*	*0.11*	*0.34*	*0.25*		*0.13*	*0.28*	*0.25*	*0.08*	*0.04*		*2.39*	
ACT 1082	Oshetna P-2	mean	69.77	0.54	15.85	2.88	nr	0.91	3.10	4.29	2.45	0.22	nr	96.76	9
		1 δ	*0.66*	*0.15*	*0.93*	*0.51*		*0.23*	*0.43*	*0.32*	*0.23*	*0.04*		*2.23*	
ACT 1076	Oshetna	mean	72.71	0.39	14.91	2.19	nr	0.64	2.26	4.05	2.66	0.20	nr	95.80	17
		1 δ	*1.93*	*0.12*	*1.43*	*0.75*		*0.57*	*0.54*	*0.68*	*0.37*	*0.07*		*4.95*	
ACT 1073	Oshetna	mean	72.81	0.32	14.85	2.17	nr	0.56	2.35	4.06	2.82	0.20	nr	96.79	8
		1 δ	*0.37*	*0.15*	*0.38*	*0.46*		*0.24*	*0.08*	*0.38*	*0.28*	*0.09*		*1.17*	
ACT 1078	Oshetna	mean	72.40	0.41	14.62	2.36	nr	0.63	2.26	4.38	2.73	0.21	nr	98.38	10
		1 δ	*0.60*	*0.06*	*0.34*	*0.25*		*0.07*	*0.13*	*0.15*	*0.06*	*0.05*		*1.62*	
Begét	Reference	mean	72.55	0.43	14.63	2.29	nr	0.66	2.31	4.20	2.72	0.21	nr	97.79	22
unpubished	Oshetna	*1 δ*	*1.00*	*0.10*	*0.70*	*0.42*		*0.26*	*0.32*	*0.36*	*0.17*	*0.05*		*1.09*	

[a]Sample name refers to the Alaska Center for Tephrochronology identification number; [b]Unit refers to unofficially named tephras from the mSRV; [c]Weight percent hydration is reported in Child et al. (1998), raw total was deduced by subtracting weight percent hydration from normalized totals. Analyses were done on a four-channel Cameca SX microprobe at the University of Alaska Fairbanks Alaska Center for Tephrochronology, see Begét et al. (1991) for analytical routine.

Reported compositions are weight percent averages of n points, normalized to 100 percent; 1 σ is standard deviation, not standard deviation of the mean; nr is not reported; P-, population; raw, original raw total.

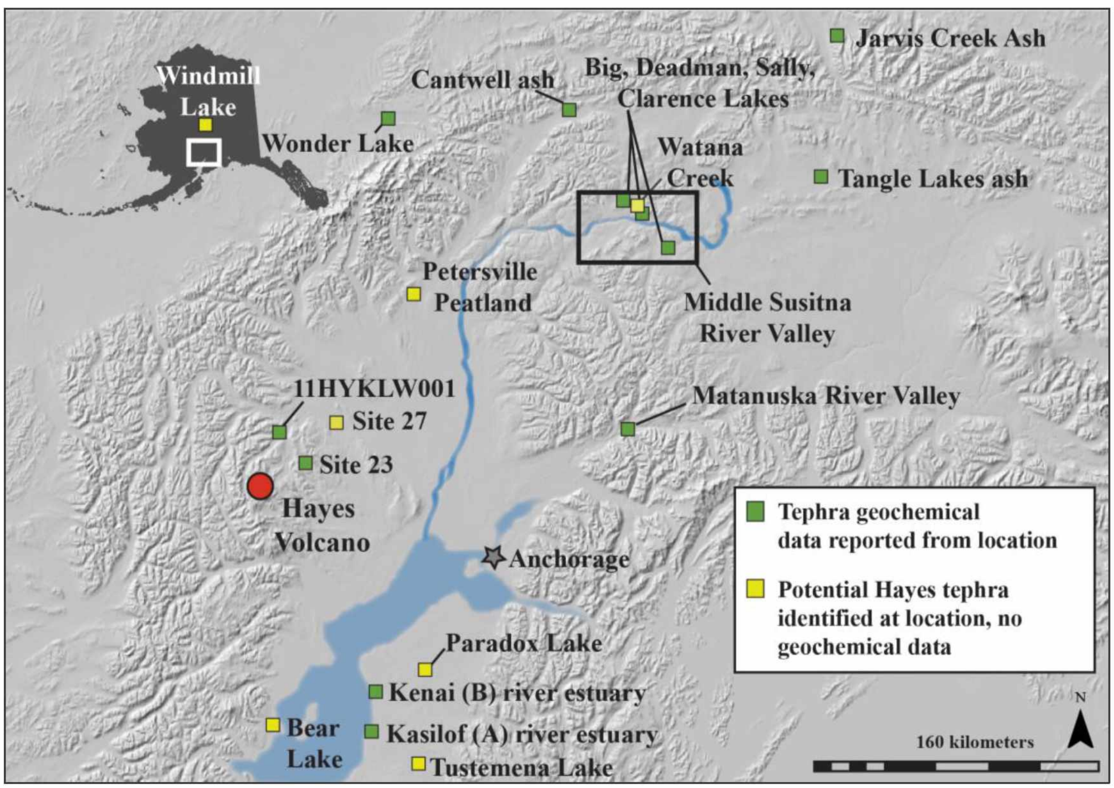


Figure 2.5. Localities with reported Hayes Volcano tephra. Stratigraphic sections and cores with reported Hayes tephra; geochemical data reported at some localities (see figure key). Locations from Begét et al. (1991); Bigelow and Edwards (2001); Bigelow et al. (2015); Child et al. (1998); Combellick and Pinney (1995); de Fontaine et al. (2007), Dilley (1988); Dixon and Smith (1990); Fontana (1988); Loisel et al. (2013); Riehle (1985); Schiff et al. (2008); Wallace et al. (2014).

at 4155–4355 cal yr B.P. (3830±60 ^{14}C yr B.P.), as well a maximum AMS date for deposition of the Oshetna tephra, at around 6800 cal yr B.P. (5790–5960 ^{14}C yr B.P.; Child et al. 1998). Peat deposits along the Kasilof and Kenai River estuaries yielded a tephra (T1) that correlated to tephra erupted from Hayes Volcano based on geochemistry, despite the samples lacking biotite, with an age range of 3690–3880 cal yr B. (3530±70 ^{14}C yr B.P., weighted average of two dates above T1 and two dates below T1); another older uncorrelated tephra at this location (T2), with two populations of volcanic glass, has an age of 5000–6000 cal yr B.P. (4980–5920 ^{14}C yr B.P.; Combellick and Pinney 1995). More recently, Bigelow et al. (2015) provide glass geochemistry of tephras found in cores from Clarence, Big, Deadman, and Sally Lakes in the mSRV. Two to five tephras were identified in each lacustrine core; however, only the Watana tephra (which was correlated based on terrestrial mSRV volcanic glass geochemistry data reported in this thesis) correlates in all lacustrine cores and with the terrestrial tephra in the area (Bigelow et al. 2015).

Other areas that the Hayes tephra have been noted based on the characteristic presence of biotite (rather than volcanic glass geochemistry), include Bear Lake (Schiff et al. 2008), Paradox and Tustemena Lakes (de Fontaine et al. 2007), Windmill Lake (Bigelow and Edwards 2001), and the Petersville Peatland (Loisel et al. 2013). While tephra attributed to Hayes Volcano are present at many localities in southcentral and central interior Alaska, it is unclear how the individual distal tephra relate to the eight proximal Hayes Volcano tephra of the Hayes tephra set H. Indeed, Riehle (1985:55) emphasizes that more research is necessary to clarify how many eruptions are represented in the Hayes tephra set H, and determine which individual proximal tephra layers are represented distally. Table 2.3 summarizes relevant research on mSRV tephra and Hayes tephra set H.

Recent geochemical characterization of another proximal Hayes Volcano tephra reference section by Wallace et al. (2014) identified eight tephra layers at the Hayes River Outcrop (their Unit III at site 11HYKLW001), located 31 km northeast of Hayes Volcano. Thorough field characterizations of the Hayes tephra set H are also provided, which are notably absent in earlier work. Wallace et al. (2014) tentatively correlate Combellick and Pinney's T1 with their tephra H, and the Jarvis Ash Bed, Tangle Lakes tephra, and Cantwell ash bed with their tephra F (Wallace et al. 2014). Basal dates for the tephra set at the Hayes River Outcrop are similar to those reported by Riehle et al. (1990) and Begét et al. (1991); however, Wallace et al.

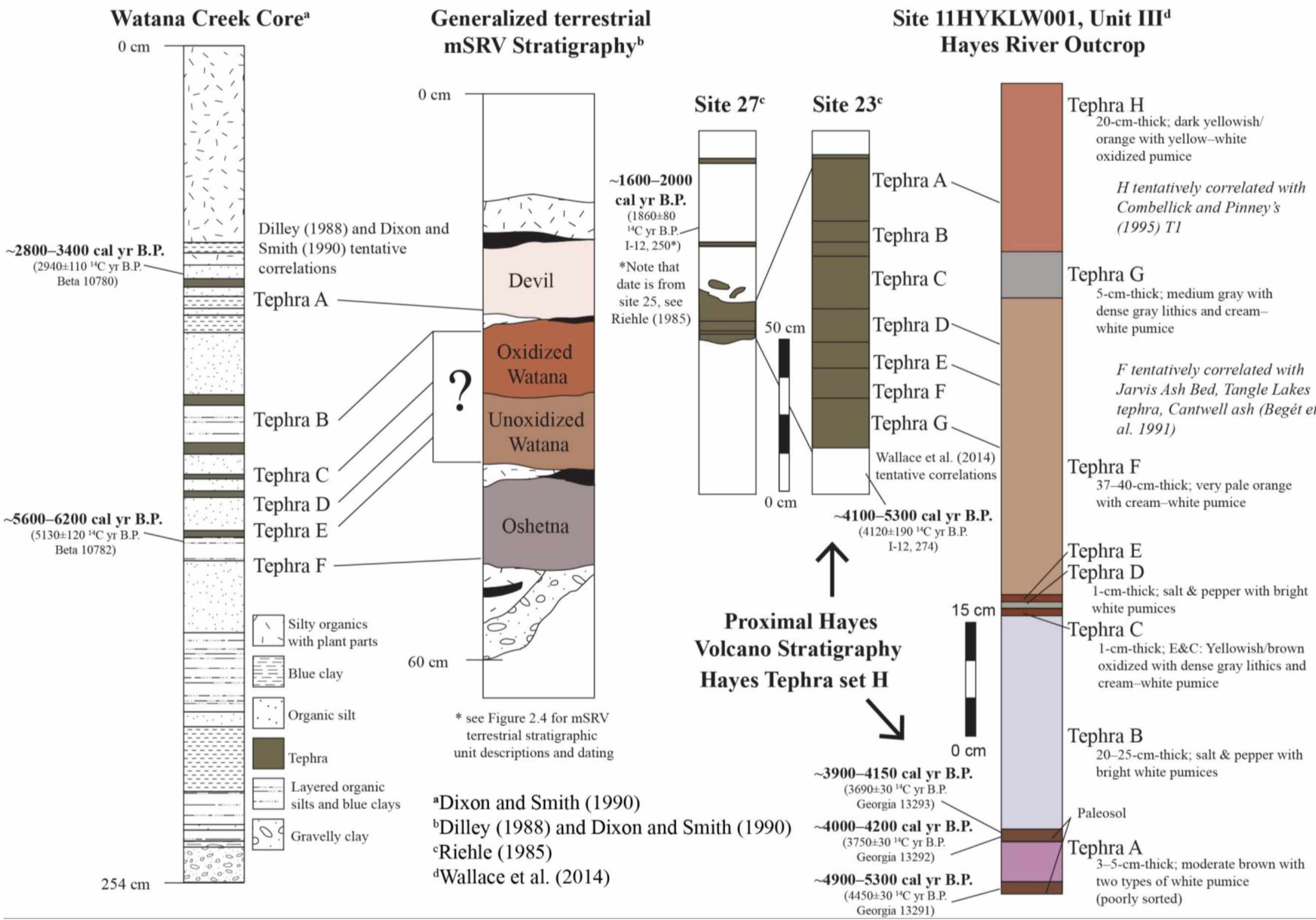


Figure 2.6. Tentative mSRV tephra and Hayes Volcano proximal tephra correlations. Adapted from sources noted above.

Table 2.3. Summary of relevant research on mSRV and Hayes Volcano tephra. Continues onto next page.

Reference	Sample Locations	Description[a]	Analyses[b]	Interpretations[c]	Associated Dates in ^{14}C yr B.P.[d]
Reger et al. (1964)	Delta River Valley (distal): one location	One 1–3-cm-thick ash	None	Jarvis ash/Jarvis Creek ash bed	None (estimated 2000–4000 years ago)
Bowers (1979)	Nenana River Valley (distal): four locations	One 0.5–7-cm-thick ash	Petrographic, glass geochemistry	Cantwell ash not correlated with Jarvis Creek Ash	3780±80 (max)
Romick and Thorson (1983)	Susitna River Valley (distal): 31 samples from 11 sites	Four tephra units from youngest to oldest: Devil tephra, 3–8-cm-thick; Upper Watana, 5–10-cm-thick; Lower Watana, 1–10-cm-thick; Oshetna, 3–5-cm-thick	Petrographic, volumetric grain size	Similar mineralogies in younger three tephras, tentative correlation with Hayes based on biotite. Oshetna distinguished by a lack of biotite. Oshetna coarsest of tephras, upper three finer and with comparable distributions	Devil: 1800±55 (min), no max; Upper Watana: 2310±220, 2340±145 (min), 2750±215 (max),; Lower Watana: 2750±215 (min),3200±195, 3200±80 (max); Oshetna: 4720±130, 3200±195 (min), 4580±780 (max)
Dixon et al. (1985)	Susitna River Valley (distal): 29 samples from 10 sites	Three to four tephra units terrestrially; six tephra deposits in lacustrine core, ranging from 0.2–4 cm thick (A youngest, F oldest)	Petrographic, volumetric grain size	Only the Oshetna tephra distinguishable based on the absence of biotite; stratigraphic evidence suggests two Watana tephras are separate, petrographically unclear	Devil tephra: 1500–1400; Watana tephras: 2700–1850; Oshetna: 5900–5200
Riehle (1985)	Cook Inlet (proximal): 31 sites sampled; site 23 Hayes reference	Seven tephra units: 23A (youngest) through 23-G (oldest). Additional younger tephra noted at site 27	Glass geochemistry	Geochemically characterized each tephra. 6 to 8 tephra northeast of vs 2 tephra south of vent	Basal age of tephra set: 4210±190 (max)
Dilley (1988)	Susitna River Valley (distal): terrestrial localities, lacustrine core, bog core	Same as Dixon et al. 1985; also two tephra units in a bog core	Glass geochemistry, petrographic	Lacustrine tephra A correlated to Devil; B-E to Watana tephra; F to Oshetna; two tephra in bog core correlated to terrestrial Devil and Watana tephra based on age	Devil tephra: 1500–1400; Watana tephras: 2700–1850; Oshetna: 5900–5200
Fontana (1988)	Matanuska River Valley (distal): 16 field stations	Nine tephra units generally <4-cm-thick, but up to 10-cm-thick (58 total tephra samples)	Glass, magnetite/ ilmenite geochemistry, petrographic	Four or five tephra units correlated to the Hayes tephra set and unoxidized Watana tephra based on age, glass geochemistry, and similarity coefficients (from Riehle 1985 and possibly Romick 1984, in Dilley 1988 data); younger and older tephras also present in area	Tephras correlated to Hayes tephra set: 3170±170 (min), 3390±180 (max); older tephra in region older than 5650±160 (min); younger tephras in region (2) younger than 2410±220 (max)
Dixon and Smith (1990)	Same as Dilley (1988)	Same as Dixon et al 1985	Mineralogic	Same as Dilley (1988)	Tephra A/Devil:1420–1516 (max); tephras B–E/Watana: 2700–1850; tephra F/Oshetna: 5900–5100
Riehle et al. (1990)	Cook Inlet: proximal and distal	Summarizes data for all known Hayes tephra deposits	Glass geochemistry, petrographic	Bilobate deposits extending south and northeast; estimates distribution of individual tephra layers comprising the set	Tephra 23-A (youngest) younger than 3500; 23-B through 23-G (oldest): 3500–3800 (max);
Begét at al. (1991)	South-central and central Alaska (distal): Jarvis Creek, Tangle Lakes, Cantwell	Five samples each of Jarvis Creek tephra and Tangle Lakes tephra, eight samples of Cantwell tephra	Glass geochemistry	Jarvis Creek Ash, Cantwell ash, and Tangle Lakes tephra corelated to each other and Hayes proximal tephra 23-C, 23-D, and 23-E	Jarvis Creek: 3360±200, 3660±275 (max); Tangle Lakes: 3660±140 (min)

[a]Description is summarized from tephra description provided in resource; [b]Analyses summarizes the tephra analyses reported in the publication, petrographic analyses may include mode of refraction indices, glass shard morphology, or percentages and abundances of mineral fraction of tephra; [c]Interpretations are those provided by the reference; [d]All dates are provided as ^{14}C yr B.P. for brevity.

Table 2.3. **Summary of relevant research on mSRV and Hayes Volcano tephra.** Continues from previous page.

Reference	Sample Locations	Description[a]	Analyses[b]	Interpretations[c]	Associated Dates in ^{14}C yr B.P.[d]
Riehle (1994)	Cook Inlet (proximal and distal)	Replicate analyses of Riehle et al. (1990) proximal reference samples from locality 23 to address variance	Glass geochemistry	Jarvis Creek, Tangle Lakes, and Cantwell ash have highest similarity coefficients with proximal sample 23-G. Hayes tephra set H proposed nomenclature	3800–3500 (from Riehle et al. 1990)
Combellick and Pinney (1995)	Kenai Peninsula (distal): Kasilof and Kenai river estuaries; peat deposits	Sampling location A: two 3-cm-thick tephra; sampling location B: one 3-cm-thick tephra and several unsampled thin tephras (<3 mm)	Petrographic, glass geochemistry	No biotite in samples. Tephra T1, present at both sampling localities, geochemically similar to Hayes tephra. 2 populations of volcanic glass in T2; ikely product of another volcano	T1 weighted average: 3530±70; T2: 4550±70 (min); 4970±100 (max)
Child et al. (1998)	Denali National Park (distal): Wonder Lake and three kettle ponds nearby	Three tephra deposits: upper FT1 tephra 5–10-mm-thick; middle FT2 tephra, 2–3-mm-thick; lower MT tephra dispersed 4–10-cm-thick	Glass geochemistry, magnetic susceptibility	FT1 correlated with the Jarvis Ash and Hayes tephra set H; FT2 correlated with the Oshetna ash; MT uncorrelated	FT1: 3830±60 (max); FT2: 5850±60 (min), 6020±60 (max)
de Fontaine et al. (2007)	Kenai Peninsula (distal): Tustumena Lake, Paradox Lake	19 tephra layers detected in Tustumena Lake, ranging from 0.1–1.6-cm-thick; 109 tephra layers recorded in Paradox Lake, ranging from 0.1–3.8-cm-thick	Magnetic susceptibility, petrographic	Correlated multiple tephra layers (3) to Hayes tephra based on unique biotite, amphibole, and pyroxene mineralogy	Tustumena Lake: upper tephra 3580±35 (max); lower two tephra 3580±35 (min), 3840±40 (max). Paradox Lake (all three): 2970±50 (min), 4055±45 (max)
Schiff et al. (2008)	Cook Inlet (distal): Bear Lake	67 tephra layers; 8-cm-thick tephra in core BL-3/B separated by 1.5 cm of brown gyttja	Petrographic	8-cm-thick tephra (both upper and lower portion) in BL-3/B correlated to Hayes tephra based on the presence of biotite	3835±35 (max)
Loisel et al. (2013)	Peterville peatland (distal): nine cores	One tephra, ranging from 15–25-cm-thick present in all peat cores	Particle texture	Tephra texture classified as sandy loam and/or silt loam in USDA Classificaton scheme; correlated to Hayes based on age	5910±60, 6370±200 (max), 3685±20, 3405±35 (min)
Wallace et al. (2014)	Hayes River Outcrop (proximal): site 11HYKLW001	Eight tephra deposits representing Hayes tephra set H, ranging from 1–40-cm-thick and named alphabetically (oldest to youngest) A through H	Glass geochemistry, magnetite/ ilmenite/ amphibole/ biotite compositions, whole rock compositions	Mostly dacitic tephra (except tephras G and H), deposits physically distinctive. Tephras B, F, G, and H most likely to correlate to distal tephras. Fe-Ti oxides distinctive between tephras. Tentative correlations: tephra H with Combellick and Pinney's (1995) T1; tephra F with Jarvis Ash Bed, Tangle Lakes tephra, Cantwell ash bed, and Riehle's (1985) G, D, or E	Tephra A: 4450±30 (max); Tephras B and above: 3690±30, 3750±30 (max)
Bigelow et al. (2015)	Susitna River Valley (distal): Clarence Lake, Deadman Lake, Big Lake, Sally Lake	Two to five confirmed tephras, 0.05–4-cm-thick (one 9.5-cm-thick tephra likely sampling disruption). Additional very fine-grained units (<0.063 mm) not analyzed	Glass geochemistry	Watana tephra is correlated in all lakes cores, correlated with terrestrial Watana tephra samples from the mSRV	Watana: 3200±30 (min), 3690±25 and 3740±20 (max)

[a]Description is summarized from tephra description provided in resource; [b]Analyses summarizes the tephra analyses reported in the publication, petrographic analyses may include mode of refraction indices, glass shard morphology, or percentages and abundances of mineral fraction of tephra; [c]Interpretations are those provided by the reference; [d]All dates are provided as ^{14}C yr B.P. for brevity.

(2014) acknowledge the discrepancy in radiocarbon dates between the mSRV tephra and proximal Hayes tephra set H and highlight the need for more geochemical data from the mSRV tephra for formal correlation. All relevant previous geochemical characterizations of tephra can be found in the supplementary file (Mulliken_2016_thesis_supplemental) that accompanies this thesis, in Table S1.

2.2.3 Hayes Volcano and plinian eruptions

Hayes Volcano is the easternmost and northernmost volcano in the Aleutian volcanic arc, located 135 km northwest of Anchorage in the Tordrillo Mountains and approximately 240 km southwest of the mSRV (Wallace et al. 2014; Waythomas and Miller 2002) (Figure 2.5). Although it is quiescently capped by glacier ice and snow today, Hayes Volcano received some attention following its discovery and recognition as the source of widespread mid-Holocene tephra in the Cook Inlet area, which currently supports the most populous city and largest airport in Alaska (Riehle 1985, 1994; Riehle et al. 1990; Wallace et al. 2014). Hayes Volcano has not exhibited any activity during historical times; however, the last eruptive period of Hayes Volcano, currently understood to extend from approximately 3600–4400 cal yr B.P., includes the largest eruption in the Cook Inlet area over the past 10,000 years (Waythomas and Miller 2002). Indeed, Riehle et al. (1990) estimate that eruptions producing the Hayes tephra set H had a total eruptive volume of 10 km^3. Individual tephra units erupted in the set could therefore represent 1.25 km^3, which Riehle et al. (1990) compares to the 1.3 km^3 May 18, 1980 eruption of Mount St. Helens.

Waythomas and Miller (2002) classify the last major eruptive phase of Hayes Volcano as plinian (Riehle et al. 1990). Plinian eruptions are very energetic and characterized by an eruption column of hot gas and steam, and copious ash and pumice (Walker 1981). Often the inertial momentum of the expanding gases and convection caused by air being sucked into the base of the eruptive column will propel it thousands of feet into the atmosphere or even into lower levels of the stratosphere (Lockwood and Hazlett 2010). Prevailing wind directions at the time of the eruption direct the resulting plume of volcanic materials and where they are deposited, and the great heights of plinian eruptions plumes allow for deposits to be widely dispersed (Walker 1981).

Often, volcanic hazards are evaluated with respect to their distance from the volcanic vent; those hazards occurring within the near vicinity of the volcanic vent (within a few km) are proximal, and those occurring farther away are distal. Distal areas primarily experience volcanic ash fallout whereas proximal areas may have a greater number of deposits resulting from processes that occur nearer to the vent (e.g. pyroclastic flows, lava flows, mud flows). After the eruption plume forms, heavier pumice particles fall out near the vent, often forming the basal proximal deposit; above the basal deposit of pumice, evidence of pyroclastic density currents may occur (Lockwood and Hazlett 2010). Pyroclastic surges form when the eruption column collapses. They have a relatively low temperature are highly turbulent during emplacement, eroding the units below them and forming deposits that exhibit cross-bedding, erosion channels, and unconformities (Lockwood and Hazlett 2010). Alternatively, pyroclastic flows may also form from column collapse, dome collapse, or magma chamber over-pressurization; pyroclastic flows have a much higher temperature and exhibit laminar flow, with thick, poorly stratified, poorly graded deposits filling valleys (Lockwood and Hazlett 2010).

Evidence of the plinian eruption sequence in the stratigraphy of proximal and distal areas is variable depending on wind dynamics at the time of the eruption and post-depositional erosion of the eruption products. Riehle et al. (1990) provide an isopach map showing the distribution and thickness of the late Holocene sequence of ashfalls from Hayes Volcano, with dacitic ashfall occurring distally up to 250 km south and 400 km northeast of the volcanic vent in the area of Cook Inlet and southcentral interior Alaska, and including the mSRV (Figure 2.7). In addition, outcrops of pumice-rich pyroclastic flow deposits and lahars, likely associated with the eruptive phase from 3600–4400 cal yr B.P., have been mapped on the lower flanks of Hayes Volcano (Waythomas and Miller 2002). More recent investigations along the Hayes River, by Wallace et al. (2014), provide basal ages of 3950–4160 cal yr B.P. (3690±30 and 3750±30 ^{14}C yr B.P.) for Hayes tephra set H deposition and postulate that their tephras B, F, G, and H, as the most prominent deposits at the Hayes River outcrop (site 11HYKLW001), are most likely to be present and identifiable as individual tephra deposits in the distal environment. Notably, proximal tephras F and H at the Hayes River Outcrop (site 11HYKLW001) were sub-sampled for compositional variation due to the thickness of these deposits (Wallace et al. 2014).

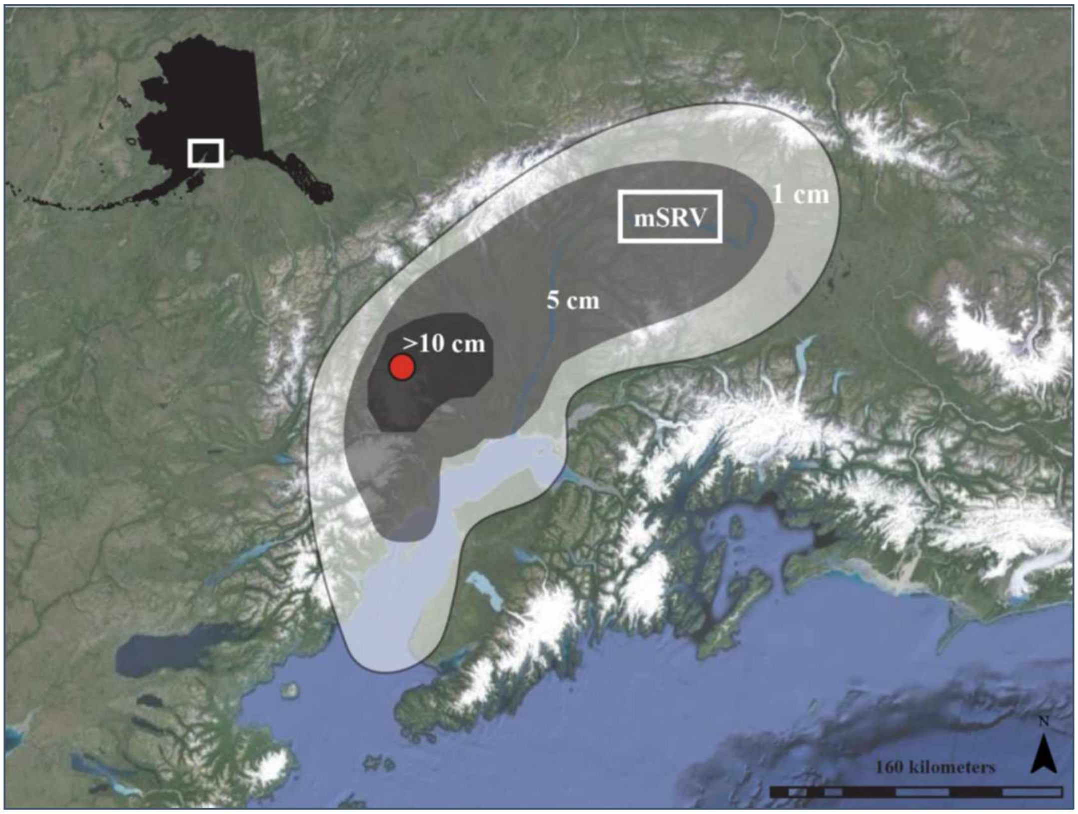


Figure 2.7. Hayes tephra set H isopach. Conservative isopach map demonstrating the extent and depth of the Hayes tephra set H; northern and western boundaries are unconstrained. Adapted from Riehle et al. (1990).

Hayes Volcano deposits older than the Hayes tephra set H have also recently been noted by Wallace et al. (2014) at the Hayes River Outcrop (site 11HYKLW001). Wallace et al. (2014) document a rhyolitic and dacitic tephrafall deposit (their tephra A) erupted prior to the Hayes tephra set H, but after 4960–5285 cal yr B.P. (4450±30 ^{14}C yr B.P.). Stratigraphically below tephra A, a complex mass-flowage deposit was emplaced on top of an older 20–30 m thick rhyolitic pyroclastic flow deposit, informally named the Hayes River ignimbrite (Wallace et al. 2014). The relationship between the mass-flowage deposit and underlying ignimbrite is not well-understood and little else is known about the individual eruptions of the last Hayes Volcano eruptive phase and how individual deposits are represented distally; correlation efforts in the mSRV will aid in addressing this issue.

2.3 Archaeological investigations in the mSRV

Much of the archaeological investigations in the mSRV have occurred in response to a proposed public works hydroelectric dam project that would entail flooding the landscape and therefore create negative impacts on cultural resources (Bacon 1978a, 1978b; Bowers 2011; Dixon et al. 1985; Greiser et al. 1985; Irving 1957). Irving (1957) reports on the first cultural resources survey of the area for the proposed Devil Canyon Dam: 11 sites were identified, both pre- and post-western contact. The mSRV was also investigated intensely from 1979–1985 as part of cultural resources investigations for another proposed dam project—the Susitna Hydroelectric Project—during which an additional 248 prehistoric and historic sites were reported, 87 percent of which are prehistoric (Bacon 1978a, 1978b; Bowers 2011; Dixon et al. 1985; Greiser et al. 1985).

The cultural resources investigations for the Susitna Hydroelectric Project (1979–1985) had the goals of locating and documenting cultural resources, addressing their significance, assessing the impacts of the proposed dam on the cultural resources, and developing a mitigation plan to lessen the impacts on the resources (Dixon et al. 1985). Survey locales were separated into areas of high and low potential for archaeological site occurrence based on proximity to overlooks, lake margins, natural topographic constrictions, stream and river margins, quarry sites, caves and rocks shelters, and mineral licks (Dixon 1985). Areas of high potential were shovel-tested; if shovel tests were positive, a test pit (40 cm by 40 cm) was excavated and information regarding the soil/sediments, ecological setting, site description, surface and subsurface artifact inventory, site size, and site disturbance was gathered, in addition to photographs. Excavation procedures followed natural stratigraphic units or arbitrary 5 cm levels, and artifacts were recorded as recovered accordingly.

Sites within the mSRV that would be directly impacted by the proposed Susitna Hydroelectric Dam were tested for site size by establishing a 4 m shovel test grid, which sometimes required extension. The topography of the landform where the site was located was mapped and used to approximate the maximum extent of the site (Dixon et al. 1985). In addition to establishing the chronological framework of sixteen stratigraphic units in the mSRV (summarized in Section 2.2.1), over 150,000 lithic artifacts and more than 140,000 faunal remains were recovered from archeological contexts (Dixon et al. 1985).

Recently, a new proposal for the Susitna-Watana Hydroelectric Dam has drawn attention to the mSRV again and Bowers et al. (2011) summarize information and previous work on cultural resources in the vicinity, highlighting specific data gaps and information needed to fill them. The need for compilation and evaluation of radiocarbon dates, as well as analysis of tephras by contemporary geochemical standards and laboratory techniques is noted. Recent cultural resources surveys have continued to assess the effects the proposed dam would have on cultural resources. New areas have been surveyed and some existing sites have been re-located and evaluated for eligibility to be on the National Register of Historic Places (Alaska Energy Authority 2012b). Recent cultural surveys have located an additional 85 archaeological sites in the mSRV (Alaska Energy Authority 2014), attesting to the rich archaeology of the area.

2.3.1 Archaeology of the mSRV and the region

Dixon (1985) synthesized archaeological data from the mSRV with previously defined cultural traditions and complexes in central interior Alaska, based on characteristics of the archaeological materials recovered. The use of cultural historical frameworks for classifying archaeological remains in central interior Alaska (and in archaeological practice in general) has been criticized due to an emphasis on description of lithic assemblage characteristics and lack of attention to explanation regarding assemblage variability or consideration of economy, site structure, or site settlement patterns (Krieger 1944; Potter 2008a; Stewart and Setzler 1938). In addition, cultural historical frameworks and classifications inherently suggest that changes in material cultural resulted from migration of different peoples or diffusion of technology (Bacon 1977; Dixon 1985). Recent archaeological research in the region, however, has emphasized consideration of multiple variables to generate new questions, hypotheses, and a greater understanding of why there are changes in material culture. Intersite analyses have found, by analyzing tool type, faunal remains, and ecological contexts through time, that the presence of technological differences represent a variety of subsistence functions within a diverse economic system (Esdale 2008; Potter 2011). This section will summarize the mSRV cultural historical frameworks established in the 1980s along with the more recent understanding of transitions in settlement and subsistence systems through time in central interior Alaska.

Human occupation of Alaska can be traced to the late Pleistocene (e.g. Goebel et al. 1996; Krasinski and Yesner 2008; Holmes 2001); technologies and subsistence economies remain rather consistent through time, but are punctuated by two distinct transitions (Potter 2008b) in the mid and late Holocene: the Northern Archaic Tradition (Ackerman 2004; Anderson 1968, 2008) and the Athabascan Tradition (Shinkwin 1977, 1979). Dixon (1985), however, identified five cultural complexes or traditions as being present in the Susitna River

Valley, from oldest to youngest, these are: The American Paleoarctic Tradition (10,600–5000 cal yr BP), Northern Archaic Tradition (5000–3500 cal yr BP), Late Denali Complex (3500–1500 cal yr BP), Athabascan tradition (1500–100 cal yr BP), and Euroamerican tradition (100 cal yr BP to present). In relation to the mSRV stratigraphy, the American Paleoarctic Tradition occurs below and possibly above the Oshetna tephra and the Northern Archaic appears between the Oshetna and lower unoxidized Watana tephra. Timing of the Late Denali complex in the stratigraphy of the mSRV is not well controlled and the Athabascan Tradition becomes established following Devil tephra deposition (Dixon 1985) (Figure 2.8). Examples of sites assigned to each tradition or complex, and their stratigraphic position relative to mSRV tephra are shown in Table 2.4. One issue associated with many of the dates corresponding to the mSRV archaeological components is relatively large standard deviations, preventing a precise understanding of the timing of occupation; however, tephra units offer a means to bracket sites by stratigraphic location.

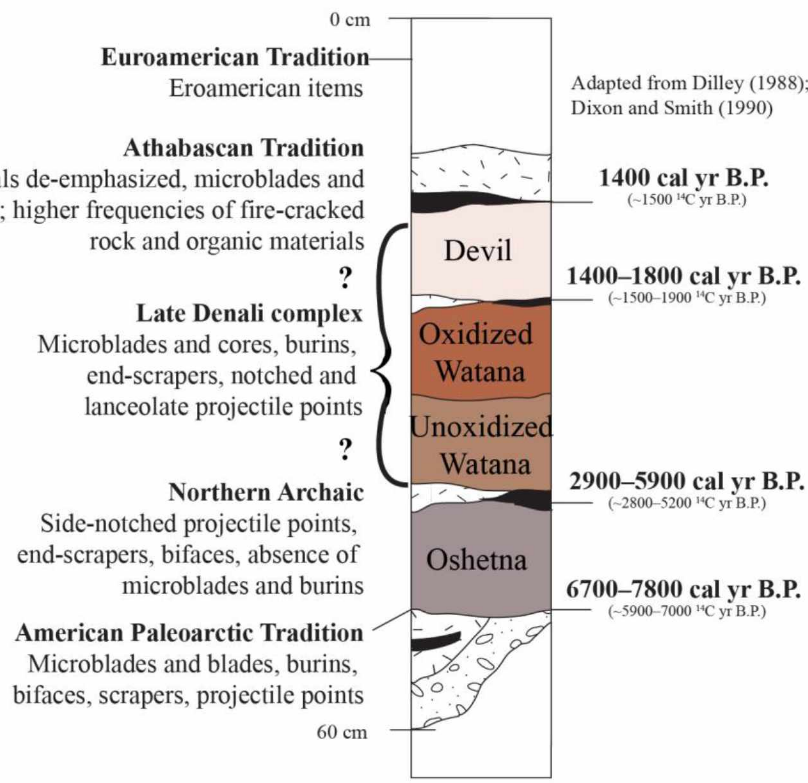


Figure 2.8. Stratigraphic occurrence of cultural traditions and complexes in the mSRV. Adapted from Dixon (1985). Note that cultural historical approaches are no longer emphasized in Alaskan archaeology.

Table 2.4. Archaeological sites assigned to cultural historical frameworks in the mSRV.

Tradition/ Complex[a]	Site[b]	Associated Dates, ^{14}C yr B.P.[c]	Artifact Assemblage/Features[d]	Faunal Assemblage[e]	Inferred site-type[f]
Athabascan Tradition	Permafrost Creek site/TLM-050, upper component	280±110(DIC-1905), 280±245 (DIC-1904)	Thermally altered rocks, 6 flakes. 2 hearths features	Caribou, medium/large mammal	Temporary campsite/hunting overlook (Dixon et al. 1985)
	Tsusena Creek site/TLM-022, upper component	300±70 (DIC-2252)	Thermally altered rocks, 1 flake	Moose, caribou, medium/large mammal	Prehistoric kill/lookout (Skeete 2008)
	Borrow C site/TLM-097, upper component	1260±80 (Beta-7845), 1400±55 (DIC-2245)	Thermally altered rocks, 1 scraper, 1 preform, 432 flakes. 2 features: bone scatter; fire-cracked rock/bone scatter	Caribou, medium to large mammal	Prehistoric kill/lookout (Skeete 2008)
	Red Scraper site, TLM-062, upper component	1380±155 (DIC-2246)	1 flake core, 1 modified flake, 1 biface fragment, 2 scrapers, 75 flakes	Caribou, medium/large mammal	Temporary campsite/hunting overlook (Dixon et al. 1985)
Late Denali complex	TLM-184, middle component	3920±100 (Beta-7842)	1 flake core, 9 modified flakes, 2 rejuvination flakes, 4 bifaces and biface fragments, 1 notched point fragment, 3 scrapers, 1882 flakes	Caribou, medium/large mammal	-
Northern Archaic Tradition	Jay Creek Mineral Lick site/TLM-143	4100±60 (Beta-5364), 4440±120 (Beta-7698), 4250±110 (Beta-7697)	1 flake core, 52 modified flakes, 13 bifaces and biface fragments, 11 scrapers, 12 notched points and point fragments, 26,782 flakes. 1 hearth.	Caribou, medium/large mammal	Tool manufacture site (Dixon et al. 1985)
	Fog Creek site/TLM-030	2310±220 (DIC-1877), 4720±130 (DIC-1880)	29 modified flakes,1 rejuvenation flake, 10 scrapers, 38 bifaces and biface fragments, 21 notched points and notched point fragments, 1 stemmed point base, 1 lanceolate point, 3 flake core and flake core fragment, 2 core tools, 2 hammerstones, 1 modified cobble, 84,386 flakes	Caribou, medium/large mammal, small mammal	-
American Paleoarctic Tradition	Jay Creek Ridge site/TLM-128	4580±780 (Beta-5362), 9,500 cal yr B.P. (Dixon 1999), 9790±60 (Beta-147295) (UAMN 2015)	7 biface fragments, 16 modified flakes, 1 scraper, 1 blade, 3 preforms, 4 triangular point fragments, 2 flake cores, 7734 flakes	Medium/large mammal	Tool manufacture site (Dixon et al. 1985)
	Tuff Creek north site/TLM-027, component III	Pre-Oshetna tephra	1 biface, 14 modified flakes, 6 blades and blade fragments, 2 rejuvenation flakes, 3 flake cores/flake core fragments, 285 flakes	-	-
	TLM-207	4030±220 (Beta-9897)	352 microblades, 1 microblade core, 4 rejuvenation flakes, 1 scraper, 602 flakes	-	-

[a]Culture tradition/complex as assigned by Dixon (1985), see Figure 2.8 for stratigraphic location; [b]Site name with State Historic Preservation Office Alaska Historic Resources Survey number for site identification, and component; [c]All dates are provided as ^{14}C yr B.P. for brevity and are from Dixon et al. (1985) unless otherwise noted; [d]Component artifact assemblage and features from Dixon et al. (1985); [e]Component faunal assemblage from Dixon et al. (1985); [f]Inferred site type from various literature, noted in parentheses.

The American Paleoarctic was originally defined based on the occurrence of wedge-shaped microblade cores and microblades, and has since been used to describe a variety of microblade and microblade core assemblages associated with terrestrial hunting in the interior (Dixon 1999). Although faunal preservation is poor in the mSRV, especially prior to 6000 cal yr B.P. (Dixon et al. 1985), data from similar ecological settings in other areas of the region inform an understanding of prehistoric behavior. From the late Pleistocene (14,000 cal yr B.P.) to mid-Holocene (6000 cal yr B.P.) microblades are found to be differentially associated with bison, wapiti, and moose in lowland areas, and settlement patterns reflect a high residential mobility with logistic camps (Esdale 2008; Potter 2008b). The first evidence of human presence in the mSRV is assigned to the American Paleoarctic Tradition, at the Jay Creek Ridge site (TLM-128) (Bowers et al. 2011; Dixon 1985). This occupation occurred between 11,200–10,800 cal yrs B.P., prior to deposition of the Oshetna tephra and during the transition from the Younger Dryas to the HTM (Bigelow et al. 2015; Dixon et al. 1985; UAMN 2015). Over 7700 lithic artifacts and 12 calcined bones were recovered as part of Jay Creek Ridge testing for the Susitna Hydroelectric Project (1979–1985), and the presence of medium to large mammal remains demonstrates procurement of those resources. The Susitna River Overlook site, although located west of the mSRV and in a lowland setting, also provides an early date of 9300–9000 cal yrs B.P. for occupation of the Susitna River Valley area, and colonization of the area is suspected to have occurred from the north (Wygal and Geobel 2012).

The Northern Archaic Tradition emerges around 6000 cal yr B.P. and distinguishes itself from earlier components by the appearance of new lithic technologies, including notched bifaces. The Northern Archaic was also originally characterized by a lack of microblade cores or microblades (Anderson 1968, 2008; Dixon 1985). Recent analyses, however, reveal that lithic assemblages containing Northern Archaic technologies often also retain technological aspects from the earlier record, such as microblades (Esdale 2008; Potter 2008c). Microblade technology is more likely to have been a long-lived technological tradition that was not absent during the Northern Archaic Tradition (Potter 2008c). Whereas subsistence economies from the late Pleistocene to mid-Holocene reflect a broad subsistence base with an emphasis on bison and wapiti in the lowlands, subsistence economies shifted during the mid to late Holocene, with increasing seasonal procurement of caribou and sheep in upland areas (Esdale 2008; Potter

2008b). The Jay Creek Mineral Lick site (TLM-143) and the Fog Creek site (TLM-030) in the mSRV were assigned to the Northern Archaic Tradition (Dixon 1985).

Initially, the Northern Archaic Tradition was investigated in relation to population replacement or diffusion, and thought to be indicative of cultural groups from the subarctic migrating north with the boreal forest and perhaps interacting with established populations (Anderson 2008; Dixon 1985). Mason and Bigelow (2008), however, use palynological and paleohydrological analyses and other proxy paleoclimate data to infer that the expansion of the Northern Archaic Tradition occurred on a complex landscape of tundra and forest, in varying climate conditions. This suggested that sites with Northern Archaic Tradition characteristic technology might actually be associated with ecotone areas that had access to both wooded and open areas of greater potential for hunting success.The Late Denali complex was originally defined because the Northern Archaic Tradition in central interior Alaska was thought to lack microblade technology; therefore, microblade technologies appearing again later in the record from 3500–1500 cal yr B.P. were assigned to the Late Denali complex (Dixon 1985). Dixon (1985) tentatively assigned an upper component at TLM-184 to the Late Denali complex, although the lithic assemblage has a notched point fragment and lacks microblades or microblade cores.

During the late Holocene (1200 cal yr B.P.), the Athabascan Tradition is characterized by a decreased emphasis on lithic technology (including the true disappearance of microblades) coincident with the increased presence of organic technology and copper, as well as evidence of food storage and large habitation areas; many archaeological sites above the Devil tephra in the mSRV are characteristic of the Athabascan Tradition (Dixon 1985; Shinkwin 1979). The Athabascan Tradition is thought to be indicative of a major shift in hunter-gatherer mobility and resource procurement patterns, with evidence of food storage (indicative of procurement of seasonally abundant resources) and habitation areas suggesting a lower residential mobility with greater emphasis on seasonal logistical mobility (Potter 2008a). Indeed, Skeete's (2008) analysis of faunal remains from 11 sites in the Susitna River Valley demonstrates that Athabascan use of the mSRV was logistically focused on hunting and processing caribou during multiple seasons.

2.4 Problems and potential solutions

Numerous radiocarbon dates and the presence of distinct tephra deposits in the mSRV have allowed researchers to investigate and establish a timeline for stratigraphic development. However, although tephrochronological work has identified Hayes Volcano as the source vent for the tephra in the mSRV, there remain issues in correlating and dating the volcanic events. Given the fact that eight tephra units are present in Hayes Volcano proximal deposits, the question remains as to how the distal mSRV tephra deposits relate to proximal deposits; does each distal mSRV deposit represent one volcanic event or more than one? Geochemical analyses of the tephra from the mSRV and proximal Hayes Volcano tephra (of Wallace et al. 2014) will address this issue. Because proximal deposits have older dates than distal deposits, correlation efforts may also aid in understanding the timing of individual proximal Hayes Volcano deposits.

Dilley (1988) highlights a potential source of contamination of terrestrial materials dated in the mSRV as downward carbon leaching, which may have caused erroneously young ages and thereby explain the discrepancy between terrestrial mSRV dates and other dates (mSRV lacustrine or Hayes tephra set H basal dates). Radiometric analyses undertaken to obtain dates in the 1980s required larger sample sizes and often multiple small charcoal specimens from similar contexts would be combined into a bulk sample to facilitate analysis. The result of this practice is an average date that is not as meaningful, and this is a problem for both stratigraphic dates and dates of cultural components in the mSRV. In addition, many of the dates produced as part of the Susitna Hydroelectric Project (1979–1985) were produced by the now defunct Dicarb Radioisotope Company. Reuther and Gerlach (2005) demonstrate that this laboratory produced significantly younger dates than other laboratories dating the same cultural components in Alaska. Therefore, archaeological components in the mSRV that were dated by Dicarb are also suspect of being inaccurately dated.

The chronological frameworks established for the mSRV, both geological and archaeological, are therefore in need of revision, especially in light of recent advances in dating techniques and increased resolution of calibration curves (Cook and van der Plicht 2007; Jull 2007; Ludwig and Renne 2000; Pettitt et al. 2003; Reimer and Reimer 2007; Telford et al. 2004; van der Plicht and Hogg 2006). Dates associated with Hayes ashfalls in other areas of Cook Inlet offer a means from which to evaluate and synthesize new dates produced as part of this study, aiding in delimiting the timing of mSRV ashfalls. While the integrity of existing mSRV archaeological component dates need to be evaluated with respect to materials, laboratories, context, and date, producing new dates in the mSRV will aid in evaluating and refining the existing archaeological framework. Indeed, Potter (2008b) emphasizes that radiocarbon data in central interior Alaska have become prolific over the past three decades; however, synthesis and regional evaluation is lacking and this project seeks to address that issue in the mSRV.

Refining the geochronological framework of the mSRV has direct implications for setting the appropriate context for the archaeological record, as archaeological components in the mSRV occur at the contact of each of the six major sedimentary units (Dixon et al. 1985). The proximity of cultural components in the mSRV to tephra deposits representing volcanic events has interested researchers, with an emphasis on questions as to how these volcanic events may have affected prehistoric populations in the mSRV (Saleeby 1984). Refining the dating of archaeological components in the mSRV is one step towards addressing these questions. Archaeological investigations as part of the Susitna Hydroelectric Project (1979–1985) documented stratigraphic locations of cultural components and materials recovered from those cultural components. Using the tephra units as discrete time marker horizons allows for cultural components located at specific stratigraphic locations to be grouped together. Established trends in the archaeological record of interior Alaska allow for expectations to be derived regarding specific variables as part of archaeological components between tephra units in the mSRV. For example, notched points typifying the Northern Archaic Tradition appear at about 6000 cal yr B.P. in interior Alaska, and persist until approximately 1200 cal yr B.P.; therefore, it is expected that notched points should be present in archaeological assemblages located stratigraphically above the Oshetna, Watana, and Devil tephras, but absent below the Oshetna tephra. Likewise, archaeological assemblages above the Devil tephra should also display changes in assemblage characteristics typical of the transition to the Athabascan Tradition, which appears around 1200 cal yr B.P. in interior Alaska. Lastly, data on the effects of volcanic eruptions that have occurred during recorded history may be used to understand the potential effects of tephra deposition in the mSRV, which has direct implications for hunter-gatherer resource acquisition.

2.5 Summary

This chapter has provided background information relevant to this study. The geological history and environmental context for the study area has been described, including stratigraphic investigations and previous analyses of tephra. Knowledge of Hayes Volcano is limited and gaps remain in our understanding of how distal tephra deposits in the mSRV relate to the proximal Hayes Volcano tephra set H, which has implications for understanding the effects of these volcanic events on prehistoric populations. A history of archaeological investigations in the study area has also been provided. A consistent problem in understanding both the stratigraphy and archaeology of the mSRV involves the existing radiocarbon dates, which complicate correlation efforts and prevent accurate understanding of the timing of tephrafalls and archaeological components. In addition, the archaeology of the mSRV has primarily been interpreted within cultural historical frameworks, which are no longer emphasized for understanding prehistoric hunter-gatherer behavior in Alaska.

While the existing chronostratigraphic framework for the mSRV may serve as a starting point from which to evaluate processes and events documented in the stratigraphic sequence of the mSRV, refining our understanding of the tephra deposits and their timing will aid in understanding the timing and nature of the archaeological record. Because resources on the landscape influence hunter-gatherer behavior, tephra deposition in the mSRV could have had an effect on mobility and resource acquisition; other volcanic events, ethnographic data and the archaeological record offer a means to evaluate how tephra may have impacted hunter-gatherers using the mSRV. Each of these broad areas of investigation are detailed in the next chapter, which describes the specific materials and methods used in this study.

Chapter 3: Materials and Methods

This chapter describes the specific materials and methods used in this study and includes five sections: Section 3.1 describes tephra samples and analyses; Section 3.2 details new radiocarbon dates obtained from the mSRV as part of this study, as well as the techniques of chronometric evaluation for existing dates; Section 3.3 summarizes the mSRV archaeological materials and methods of analysis; Section 3.4 briefly discusses qualitative model building for understanding effects of tephra deposition; and, Section 3.5 describes the theoretical approach used in this study: human behavioral ecology.

3.1 Tephra analysis

Correlation of tephra relies on comprehensive characterization of the tephra deposit, which should include field characterization, mineralogy, petrology, glass shard morphology, and glass geochemistry. Although tephra from the mSRV have been previously geochemically analyzed, advances in analytical techniques and recent characterization of proximal Hayes Volcano tephra samples merited re-analysis. This section will summarize the samples and methods used to characterize and correlate tephra geochemically as part of this analysis.

3.1.1 Tephra sample selection

Tephra samples analyzed in this study were collected as part of archaeological investigations for the Susitna Hydroelectric Project (1979–1985) (Dixon et al. 1985) and are housed in the University of Alaska Museum of the North (UAMN) archaeology collections. A total of 61 tephra samples from 19 archaeological sites are analyzed as part of this study, with multiple samples of each tephra unit from multiple locations analyzed in an attempt to capture and understand the variation of each deposit (see Appendix A for tephra sample descriptions and provenience information; see Appendix B for site descriptions and stratigraphic sections from mSRV archaeological sites with tephra samples).

Of the 61 tephra samples, 23 have information indicating clearly the stratigraphic location from which the sample was taken, allowing these samples to be confidently assigned to individual informally named mSRV tephra units (i.e. the Devil, upper oxidized Watana, lower unoxidized Watana, and Oshetna). In many instances, these stratigraphic tephra units were separated by other discrete stratigraphic deposits or buried soil horizons. A total of seven Devil tephra, 12 Watana tephra (including two sub-samples of the upper oxidized Watana and three sub-samples of the lower unoxidized Watana), and four Oshetna tephra samples are analyzed as reference material for the mSRV (Table 3.1, Figure 3.1). Other samples with ambiguous stratigraphic assignment (e.g. "upper tephra" or "lower tephra") were also included for analysis with the goal to use geochemical analysis to aid in distinguishing these tephra and then assigning them to a specific tephra unit (Devil, Watana, or Oshetna).

The Watana tephra was predominantly sampled in bulk during the 1980s, despite differences in texture and color, and occasional sub-units found between the upper oxidized and lower unoxidized portions. Archaeological site TLM-027 is one of the few locations where the Watana tephra was bulk sampled, and the upper oxidized and lower unoxidized portions of the Watana tephra were also sub-sampled separately. This site is located south of the Susitna River and north of the mouth of Fog Creek on a knoll at an elevation of 487 meters above sea level (Dixon et al. 1985; Figure 3.1). Initial testing as part of the Susitna Hydroelectric Project (1979–1985) described the stratigraphy of test pit N144/E98 at TLM-027 in detail, and tephra sampling locations were noted (Figures 3.2 and 3.3). Because the tephra samples taken from TLM-027 have the best stratigraphic control, they are used as an mSRV reference tephra to facilitate correlation between mSRV and Hayes Volcano tephra.

3.1.1.1 Proximal Hayes Volcano reference tephra

Hayes Volcano has been suggested as the source tephra for units found in the mSRV due to the unique presence of the mineral biotite—associated with Hayes Volcano—which is present in the Watana and Devil tephras (Romick and Thorson 1983), as well as the proximity of the mSRV to this volcano (see Figure 2.5). Volcanic glass populations within the Hayes tephra set H have been previously characterized geochemically, and the units have been noted for their geochemical similarity (Begét et al. 1991; Riehle 1985; Wallace et al. 2014). In addition, Romick (1984, in Dilley 1988) documented the geochemical similarity of volcanic glass populations within mSRV tephra. Generally, glass geochemistry collected on different probes are comparable (Kuehn et al. 2011), but given the known similarity of tephra deposits in the mSRV, nine proximal Hayes Volcano reference tephra samples from the Hayes River Outcrop (site 11HYKLW001) of Wallace et al. (2014) were obtained and re-analyzed using the same

Table 3.1. Archaeological reference tephra from the mSRV.

Unit[a]	Site[b]	AT #[c]	UAMN #[d]	Provenience[e]	Description[f]
Devil	TLM-027	AT-3184	UA81-243-0491	N144/E98 (40x40 test hole), strata 3	Upper "Devil" tephra
	TLM-027	AT-3181	UA81-243-0491	N101/E100, North Wall, 13–15 cmbsd	Upper "Devil" Pinkish-grey tephra
	TLM-088	AT-3194	UA81-248-0023	Test 1, 7–8 cmbs	Devils (upper grey)
	TLM-096	AT-3205	UA81-250-0007	Test 2, West Wall, 9 cmbs	Pinkish white (Devils)
	HEA-189	AT-3221	014-131	N500/E94, 20-25 cmbs, level 4	Devil tephra
	TLM-143	AT-3442	UA82-083	N95/E100, South Wall, 12–14 cmbd, Unit 3	Devil tephra
	TLM-128	AT-3445	UA82-068	N92/E99, East Wall, 19–23 cmbd, unit 2	Devil tephra
Watana Bulk	TLM-027	AT-3182	UA81-243-0491	N101/E100, North Wall, 16–19 cmbsd	Middle "Watana" Lt. Brown tephra
	TLM-088	AT-3195	UA81-248-0023	Test 1, 13–15 cmbs	Watana (yellow brown)
	TLM-096	AT-3206	UA81-250-0007	Test 2, South Wall, 9 cmbs	Yellow Brown (Watana)
	HEA-189	AT-3219	011-266	N499/E90, SE Quad, South Wall, 54–59 cmbs, level 6 (Above Feature 6)	Hayes Watana tephra
	HEA-189	AT-3220	014-163	N499/E90, SW Quad, 64–69 cmbs, level 8 (Collected as control matrix in similar provenience to Feature 6)	Hayes Tephra
	TLM-130	AT-3440	UA82-070	N95/E99, East Wall, 14–17 cmbd, unit 4	Unit 4 within Watana
	TLM-130	AT-3441	UA82-070	N97/E99, East Wall, 6–8 cmbd, unit 4	Unit 4 within Watana
Upper Oxidized	TLM-027	AT-3185	UA81-243-0491	N144/E98 (40x40 test hole), strata 4	Middle "Watana" Super-oxidized black tephra
	TLM-027	AT-3186	UA81-243-0491	N144/E98 (40x40 test hole), strata 5	Middle "Watana" Oxidized dark brown tephra
Lower Unoxidized	TLM-027	AT-3187	UA81-243-0491	N144/E98 (40x40 test hole), strata 6	Middle "Watana" light brown tephra
	TLM-128	AT-3444	UA82-068	N92/E99, North Wall, 29–33 cmbd, unit 3	Unoxidized Watana Tephra Sample
	TLM-040	AT-3448	Unit 4-B	Unit 4-B (Dilley 1988)	Very pale brown (10YR 7/3) loam; Watana tephra; powdery; typical oxidized zone absent; abrupt lower contact
Oshetna	TLM-027	AT-3188	UA81-243-0491	N144/E98 (40x40 test hole), strata 8	Lower "Oshetna" Grey tephra
	TLM-027	AT-3183	UA81-243-0491	N101/E100, North Wall, 20–22 cmbsd	Lower "Oshetna" Lt. Grey tephra
	TLM-055	AT-3193	UA81-246-0013	Test 1, North Wall, depth not given	Lower "Oshetna"
	TLM-088	AT-3196	UA81-248-0023	Test 1, 17–19 cmbs	Oshetna (lower grey)

[a]Unit refers to unofficially named tephras from the mSRV; [b]State Historic Preservation Office Alaska Historic Resources Survey number; [c]Alaska Tephra Laboratory and Data Center identification number (AT #); [d]University of Alaska Museum of the North accession number or identification number; [e]Provenience refers to the specific location the archaeological sample was obtained from; [f]Description provided by archaeological documentation.

Note: cmbd is cm below datum, cmbs is cm below surface, cmbsd is cm below square datum.

analytical routine as that of the archaeological tephra samples from the mSRV. These samples came from seven different tephras, two of which were sub-sampled (thus nine samples total). Analysis of these proximal samples was undertaken in order to prevent possible inter-laboratory errors and to improve the potential for correlation between the mSRV tephra and Hayes Volcano tephra. Given the high frequency of volcanic eruptions depositing tephra in the Cook Inlet region (e.g. de Fontaine et al 2007; Schiff et al. 2008), volcanoes that erupted within the established timeframe of the mSRV tephra are discussed in the results chapter; however, correlations to other source volcanoes is beyond the scope of this study.

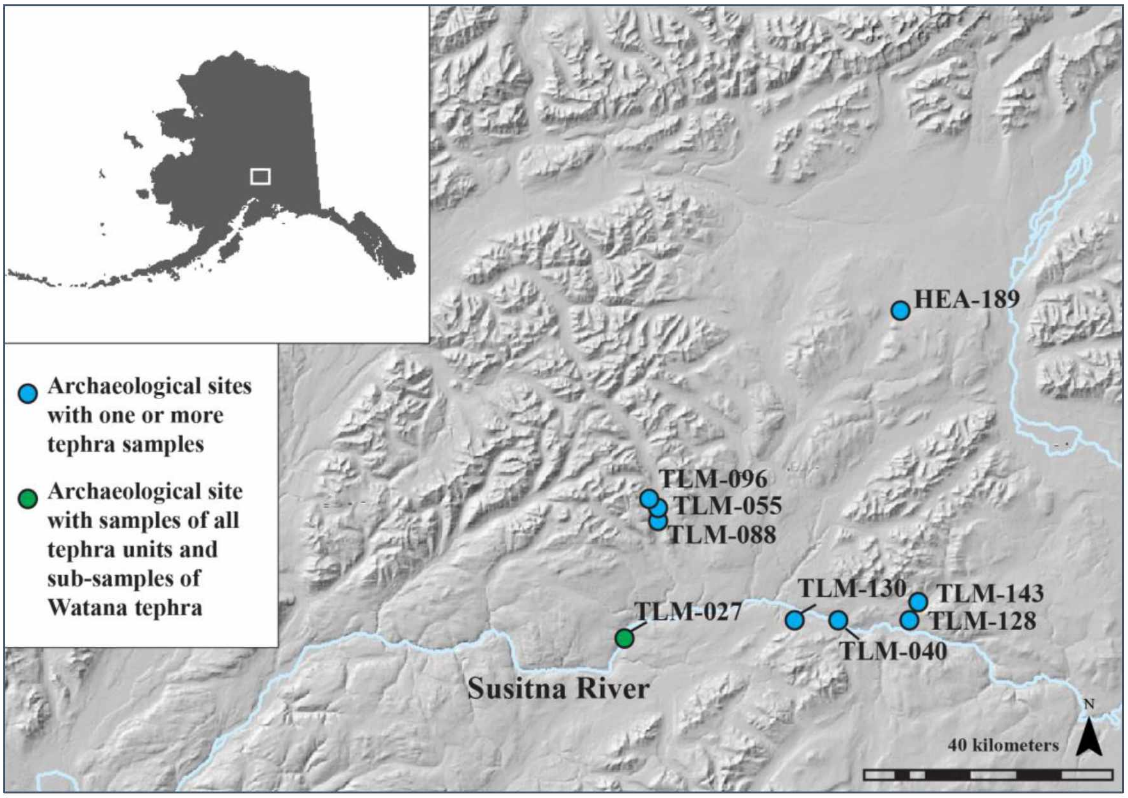


Figure 3.1. Archaeological tephra sample locations in the mSRV. Note that only archaeological sites with tephra samples including information indicating where the sample was taken from in the stratigraphy are included in this figure. The names of archaeological sites with unidentified tephra are in Appendix A.

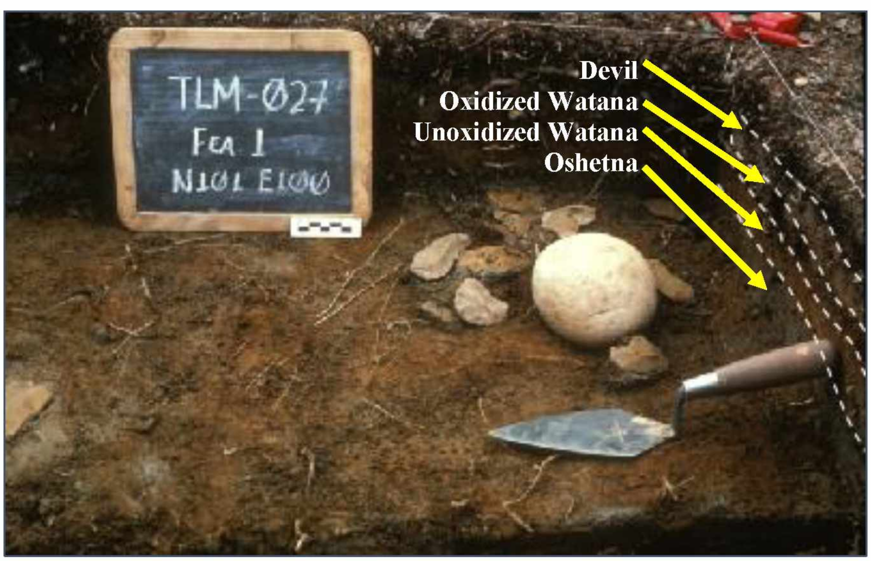
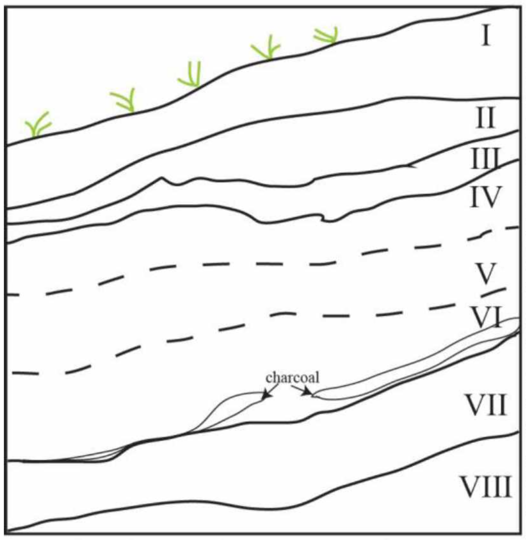


Figure 3.2. TLM-027 stratigraphy. At TLM-027 test unit N101/E100, samples of the Devil tephra, bulk Watana tephra, and Oshetna tephra were taken. At this location, the Devil tephra is described as a light pinkish gray tephra 13–15 cm below unit datum; the Watana as a yellowish brown tephra 16–19 cm below unit datum; and the Oshetna as a light gray tephra 20–22 cm below unit datum. The stratigraphy is displayed in greater detail at test unit N108/E101 (Figure 2.3); however, no tephra samples were taken from test unit N108/E101 (UAMN 1981).



"Base of test hole contact with strong brown oxidized coarse sand gravel pebbles matrix."

* Tephra samples taken from strata III, IV, V, VI, VIII

I: Dark brown organic layer containing roots and mosses.

II: Finely divided organics very dark in color and contains some carbon. Clear contact with overlying organic material. Contact with underlying strata is clear although slightly irregular.

III: Thin lens of brownish gray silt-sized particles, tephra. Although lense (sic) is continuous it varies from 0–3 cms in thickness. Contact at lower extent is clear to sharp.

IV: Black reddish brown mineral zone with granular texture. Material becomes powdery with drying in hand. Sharp contact at upper extent. Gradational contact at lower extent.

V: Strong brown oxidized matrix. Similar to 4 in granular appearance. May contain some sand. Gradational boundaries at both the upper and lower contacts.

VI: Yellowish brown sand-tephra. Poorly sorted. Contains carbon at lower extent. Sharp contact with underlying strata. Material is not as coarse in appearance as 4 and 5 and powders in hand with drying into a very fine material.

VII: Carbon lens, which is almost continuous. In some places it rests on the contact with the underlying strata while in other spots there is a thin lens of the yellowish brown matrix beneath it.

VIII: Grey poorly sorted sand-tephra. Fine sand texture although some of the material powders in palm of hand when drying. Clear to sharp contacts at upper and lower extent with fairly even boundaries.

Figure 3.3. TLM-027 N144/E98 stratigraphy. Stratigraphy of test pit N144/E98 at archaeological site TLM-027, and unit descriptions; tephra samples taken from units in this test pit are used as mSRV reference tephra samples because the Watana tephra was subsampled (from units IV, V, VI) at this location. Adapted from pg. 113–114 of King's 1981 notebook in the UAMN archaeology collections (UAMN 1981).

3.1.2 Tephra sample processing and preparation

Tephra samples were processed at the U.S. Geological Survey Alaska Volcano Observatory (USGS AVO) Tephra Laboratory in Anchorage, AK. Bulk samples of tephra collected from archaeological sites in the mSRV were wet sieved with tap water to remove fine ash particles and separate the sample into three size fractions. Disposable nylon mesh secured in plastic frames rather than traditional sieves were used for wet sieving to prevent contamination with other samples. Aggregates of sample material sometimes required disaggregation by rubbing the sample between fingers. During wet sieving, samples were separated into fractions of larger than 250 microns, between 250 and 125 microns, and between 125 and 63 microns, after which they were filtered through a hardened ashless paper filter and oven-dried at 70° C.

Following processing, samples were examined under a binocular microscope to confirm that they were volcanic by the presence of glass shards, pumice grains and/or crystals coated in glass. Typically, the 250–125 micron size fraction was used to make polished mounts (Mann Petrographics, NM, USA) for electron probe microanalysis (EPMA). Prior to EPMA, polished mounts were coated with carbon to create a conductive surface for analysis.

3.1.3 Tephra geochemistry

Characterization of the glass component of mSRV tephra was undertaken through EPMA, a method of single-point geochemical analysis that allows for data to be collected from areas as small as 5–10 microns on a sample surface. The ability to characterize individual grains is ideal for tephra analysis where pumice grains and glass shards are often vesicular and fine-grained. Grain discrete analysis also allows for identification of different populations of glass compositions within a sample, enabling evaluation of the tephra layer as one discrete volcanic event or a composite of multiple overlapping events, which has implications for the use of the layer as a discrete isochron (Lowe 2008).

The electron microprobe functions by exposing a known area of a sample to a beam of electrons, which results in ionization and fluorescence of the sample. Ionization is a process by which the incoming electrons, which have an energy level above the minimum ionization potential of orbital electrons of atoms, interact with orbital electrons causing them to eject from their electron shells and leaving the atoms unstable (Potts 1987). Fluorescence is the process by which atoms become stable again, as higher energy electrons fill the void left by the ejected electrons (during ionization), emitting energy as X-rays in the process. Because every atom has electron orbitals with characteristic energies, the X-rays that are emitted during fluorescence are characteristic of certain elements (Potts 1987). During EPMA, both the energy (accelerating voltage) and number of electrons (beam current) being sent down the electron beam to interact with the sample are adjustable depending on the goals of the analysis, and affect the depth at which electrons penetrate and interact with the sample and number of X-rays that are generated from the sample (Goldstein et al. 2003).

During EPMA, wavelength dispersive spectrometry (WDS) is used to count characteristic x-rays generated from the sample, which may then be quantified for the composition of the sample by comparing the X-ray count rates to geological standards of known composition (Potts 1987). Underlying WDS is Bragg's law, which defines the relationship between the wavelengths of characteristic X-rays generated from the sample, the spacing between the planes of atoms in a crystal which scatters the X-rays, and the angle at which the X-rays are scattered from that crystal after entering it (Goldstein et al. 2003; Potts 1987). Crystals with specific lattice spacings are selected depending on the element of interest, and the angle at which the crystal is positioned relative to the sample is specified so that only those X-rays with certain wavelengths will be reflected from the crystal to the X-ray detector, both of which have carefully engineered positions defined by the Rowland circle (Potts 1987). X-rays characteristic of the elements of interest must therefore be individually counted when using WDS; however, electron microprobes often have multiple WDS spectrometers, which decreases analysis time.

Tephra samples were analyzed in two sessions on the UAF Advanced Instrumentation Laboratory JEOL JXA-8530X electron microprobe, using identical WDS analytical conditions. Analyses took place from January 29 to February 8, 2015, and April 14–15, 2015. Analytical conditions utilized were an accelerating voltage of 15 kilovolts, a beam current of five nanoamps, and beam size of five microns. Standards with published compositions were used to calibrate the instrument (Table 3.2). Si, Al, Fe, Ca, Na, Mg, Mn, and Ti were counted for 20 seconds, and K, Cl, and P were counted for 10 seconds. Multiple points of analysis (5–10) were routinely collected on secondary working standards, KN18 volcanic glass and Rhyolitic Glass 216 (USNM 72854 VG-568), to monitor instrument drift. At least 25 points of analysis were collected on each tephra sample, if possible; however, some samples did not contain enough volcanic glass shards thus fewer points were analyzed. X-rays characteristic of each element were quantified into percent oxide compositions in the Probe for EPMA program (version 10.8.1; Donovan 2015) using the CIT-ZAF correction, which considers matrix effects of atomic numbers (Z), absorption (Z), and fluorescence (F) on the calculation of the sample composition.

Table 3.2. Analytical conditions of electron probe microanalyzer at the University of Alaska Fairbanks Advanced Instrumentation Laboratory.

Element	Standard used to calibrate[a]	Analytical Crystal - Spectrometer Number	Duration of Peak Counts (secs)
Na	Talbite (615)	TAP - 4	20
Mg	MgO (340)	TAP - 4	20
Al	Orthoclase (302)	TAP - 5	20
Si	Wollastonite (333)	TAP - 5	20
P	Apatite (332)	PET - 2	10
Cl	Scapolite (231) USNM-R6600-1	PET - 2	10
K	Orthoclase (302)	PET - 2	10
Ca	Wollastonite (333)	PET - 1	20
Ti	Ilmenite (617) (68ILM)	PET - 1	20
Mn	Willimite (328)	LIF - 3	20
P	Hematite (308)	LIF - 3	20

[a]All primary standards used to calibrate the JEOL JXA-8530X electron microprobe were available through the UAF Advanced Instrumentation Laboratory, standard identification number in parentheses; 5–10 points on secondary standards KN18 volcanic glass and Rhyolitic Glass 216 (USNM 72854 VG-568) were routinely analyzed to monitor instrument drift.

3.1.4 Data correction and filtering

Despite electron microprobe calibration using primary standards, variations in x-ray counts (and therefore oxide concentrations calculated from them) can occur due to drift in probe current and mechanical repeatability of wavelength dispersive spectrometers (Potts 1987). Because secondary standards with known concentrations are analyzed routinely throughout the analysis session, they may be used to correct for instrument drift. For this analysis, KN18 and Rhyolitic Glass 216 (USNM 72854 VG-568), both with published compositions, are used to correct for instrument drift during tephra analysis.

To correct for instrument drift, analyses of secondary standards are compared to their published standard compositions, taking into consideration oxide averages and standard deviations. Corrections are calculated when the analyzed secondary standard compositions differ from the published secondary standard compositions by at least one standard deviation. Because secondary standard analyses bracket unknown tephra analyses, the corrections applied to a secondary standard analysis are also applied to the suite of unknown tephra samples analyzed between two standards. This process is repeated for each suite of analyses of unknown tephra samples followed by an analysis of secondary standards. Appendix C presents a complete summary of methods of correction for instrument drift.

After data are corrected for instrument drift, oxide concentrations are normalized to account for volatiles (usually magmatic water), which entails re-calculating the sum of the oxides to equal 100% (note that original raw totals are presented, however). Following normalization, individual points of analysis are scrutinized closely to identify and remove all analyses of non-glass material. Data that fail to meet the following criteria, established to identify non-pure glass analysis (K. Wallace personal communications 2014), were removed from the dataset:

1) original analytical totals less than 95% (indicative of partial epoxy analysis),
2) MgO greater than 15 weight percent (indicative of mafic mineral analysis),
3) Al_2O_3 greater than 25 weight percent (indicative of felsic mineral analysis), and
4) FeO greater than 15 weight percent (indicative of mafic mineral analysis).

Averages and standard deviations are calculated following removal of points that are likely not volcanic glass. These data are scrutinized further to look for sub-populations that result from either heterogeneous glass (i.e. magma mixing) or multiple discrete magma compositions (e.g. contamination from other deposits). Populations of glass compositions are defined as points of analysis within a sample that have similar geochemical composition, usually within one standard deviation for each oxide. Generally, if the standard deviation of a sample oxide mean is greater than one, sub-populations are distinguished and individual points with unique compositions are also noted.

3.1.5 Statistical analysis of tephra geochemical data: SIMAN similarity coefficient for correlation

In characterizing and attempting to correlate a specific tephra unit, the internal variability of elemental and oxide concentrations in all deposits need to be evaluated and analytical errors should be considered (Sarna-Wojcicki and Davis 1991). Tephra correlation typically relies on calculation of the similarity coefficient, and will therefore be used in this study (Lowe 2011). A similarity coefficient is used for measuring multivariate similarity between samples, and may be used to produce a matrix of comparisons between all samples. It is an average ratio of variables (in this case, major oxides) between two samples. The smaller value is divided by the larger value for each variable in the two samples, allowing for equal consideration of variables with minute and major quantities in the samples. Early tephrochronological applications of the similarity coefficient did not consider standard deviations or analytical precision (Brochardt et al. 1972). In this analysis, the SIMAN coefficient with the weighting option of Brochardt (1974) is used, which also considers the relative analytical deviation corresponding to the detection limit (Equation 1, from Brochardt 1974).

The weighting option of the SIMAN similarity coefficient allows for the error level (ERLEV) to be manipulated and specific oxides (X_i) may also be considered in calculation of the coefficient. These weighting options prevent oxides with high relative errors from being considered in the correlation, which could result in erroneous correlations. Decreasing the ERLEV value allows for greater weights to be assigned to those oxides with lower relative standard errors when calculating the coefficient, and potential exclusion of those oxides with high standard errors (thereby reducing the number of variables that are considered in calculation of the coefficient and increasing the similarity coefficient calculated from those variables).

Equation (1): SIMAN Similarity Coefficient with Weighting Option (from Brochardt 1974)

$$d_{(A,B)} = \frac{\sum_{i=1}^{n} R_i g_i}{\sum_{i=1}^{n} g_i} \qquad g_i = 1 - \sqrt{\frac{(\sigma_{iA}/X_{iA})^2 + (\sigma_{iB}/X_{iB})^2}{ERLEV}}$$

where:

$d_{(A,B)}$ = similarity coefficient between samples A and B
i = element number
n = number of elements
$R_i = X_{iA}/X_{iB}$, if $X_{iA} < X_{iB}$ -or- $R_i = X_{iB}/X_{iA}$, if $X_{iB} < X_{iA}$

ERLEV (error level) = relative analytical deviation corresponding to the detection limit (determined by investigator as the maximum relative deviation beyond which the presence of absence of a particular variable is uncertain). I choose a ERLEV = 0.70, which excludes Mn, Cl, and P_2O_5 from being used for correlation

g_i= weighting factor that determines the contribution of variable i to the SIMAN coefficient
X_{iA} = concentration of element i in sample A
X_{iB} = concentration of element i in sample B
σ_{iA}= 1 standard deviation for X_{iA}
σ_{iB}= 1 standard deviation for X_{iB}

Calculation of the SIMAN coefficient for this analysis does not incorporate oxides present in abundances of less than half a weight percent, due to analytical sensitivity. Consequently, MnO, Cl, and P_2O_5 are excluded. Following Begét et al. (1991), similarity coefficients greater than 0.90 are interpreted as representing correlation between tephra layers (i.e. same volcanic source, different eruption), while values greater than 0.95 are considered indicative of the same volcanic event or members of the same set.

Brochardt (1974) also defines a procedure for identification of groups using the SIMAN coefficient. In order to understand the geochemical variability within archaeological tephra layers, Brochardt's (1974) method for selecting groups is used to correlate and identify geochemical groups within multiple samples of each tephra unit. Populations for the two samples with the largest similarity coefficients are averaged and new similarity coefficients are calculated between the averaged first group and other samples. A similarity coefficient value below which correlation is not accepted is established as 0.95, and is used for evaluating whether additional samples may be included in the first group when new similarity coefficients are calculated between the first group and the remaining samples. The sample with the highest acceptable similarity coefficient above 0.95 with the first group is then averaged with other data from the first group and the process is continued until no acceptable similarity coefficient values are calculated for inclusion into the first group. This process is repeated for identification of a new second geochemical group, if necessary.

3.2 Chronometric evaluation

Original investigations of the mSRV occurred during the 1980s, and many bulk charcoal samples were radiocarbon (^{14}C) dated using the radiometric technique to establish a chronology for the area; however, there have been recent refinements to ^{14}C measurements and age assays, including the availability of AMS analyses and the development of high resolution calibration curves and more sophisticated statistical techniques. This merited evaluation of mSRV original dates and the chronology established from them. This evaluation was done in order to refine the chronology of the mSRV and to permit a more informed consideration of the archaeological record in the study area. This section summarizes the new ^{14}C samples submitted for analysis as part of this study, factors considered when evaluating existing ^{14}C dates for consideration in this study, and methods of calibration and chronology evaluation.

3.2.1 Radiocarbon sample selection

Six samples collected during the Susitna Hydroelectric Project (1979–1985) (Dixon et al. 1985) investigations that have since been housed at the UAMN in clean aluminum foil were selected for dating as part of this study. The integrity of the samples was reliant upon the original sample collector notes and samples were selected only if adequate provenience information was available. Five samples are associated with five different cultural components at four archaeological sites—TLM-050, TLM-143, TLM-216, and TLM-217 (two dates from two different components)—while one of the samples is a stratigraphic sample of charcoal from archaeological site TLM-134 (Table 3.3, Figure 3.4). Most are bulk samples, with numerous individual charcoal pieces, along with matrix, and archived together in aluminum foil. For this study, individual charcoal fragments large enough for AMS dating were removed from bulk samples with tweezers and split (for later species identification) prior to submission for dating.

The nature of sample collection and submission during the Susitna Hydroelectric Project (1979–1985) investigations does not allow for ^{14}C dates produced during the 1980s to be directly

Table 3.3. Samples submitted to the University of Georgia Center for Applied Isotope Studies for dating as part of this study.

Sample #[a]	Site[b]	Location[c]	Material[d]	Type[e]	Provenience[f]	Sample Notes[g]	Associated Dates, ^{14}C yr B.P.[h]	Lab #[i]
UA80-157-1	TLM-050	Above Devil tephra	Charcoal	Cultural	Test 1, Hearth 2, 28–35cmbs	Charcoal sample with dirt-picked up from soil matrix; hearth feature at upper contact of Devil tephra; lower contact of root mat	280±245 (DIC-1904; UA80-157-1)	UGAMS-22178
UA84-59-346	TLM-217	Above Devil tephra	Charcoal	Cultural	N100/E98, NW Quad; 2/3 contact between organic mat and Devil tephra, 1b/3	Charcoal plus matrix and rootlets; small pieces ¼ inch; upper component is concentrated in a charcoal-rich layer (unit 2) and the contact between the fine organic layer (1b) and Devil tephra (unit 3)	2070±60 (Beta-9899; UA84-59-354)	UGAMS-22182
UA84-58-143a,b	TLM-216	Between Watana and Devil tephra	Wood	Cultural	N101/E100, X:37, Y:48, Z:18–20cmbs	From cultural unit positioned stratigraphically between the Devil and Watana tephras; sample is from an isolated piece of wood	1670±50 (Beta-9898; UA84-58-143); 1880±50 (Beta-9892; UA84-58-143); 1530±80 (Beta-10125; UA84-58-143)	UGAMS-22181
UA84-59-355	TLM-217	Between Watana and Devil tephra	Charcoal	Cultural	N101/E98, SE Quad, X:90-100cm, Y:15cm, Z:21–23cmbs	Component is represented chiefly by a homogenous brown silty layer containing abundant burned bone fragments, charcoal, and lithic artifacts (Unit 4), underlying the Devil tephra (Unit 3) and above oxidized Watana tephra (Unit 5a); unit 4 appears to be a culturally deposited unit	1770±190 (Beta-10791; UA84-59-354)	UGAMS-22183
UA82-083-1703	TLM-143	Between Oshetna and Watana tephra	Charcoal	Cultural	N95/E100; X:15, Y: 35, Z: 26–27 cmbs	Charcoal, carbonized matrix, bone fragments, lithics; sample from beneath hearth rock in feature 3, from bottom of feature 2&3 component; older than 3200 years before present, beneath Watana; contains rootlets; maximum limiting date for the feature 2&3 component	4440±120 (Beta-7698; UA82-83-1701); 4250±110 (Beta-7697; UA83-216-11); 4100±60 (Beta-5364; UA82-83-1698)	UGAMS-22179
UA82-74-4	TLM-134	Below Oshetna tephra	Charcoal	Strati-graphic	Test pit 1, 40 M from SW datum, X:33, Y:18, Z:11–13cmbs, In unit 6, below Oshetna	Sample from unit 6, below Oshetna; sample was surrounded by unit 6 matrix, will date the middle of unit 6. Sample consists of 2 large chunks of charcoal (2cm cubed) and several smaller pieces all from one large chunk that was broken during excavation; there is no reason to suspect soil contamination because of careful extraction of sample	None	UGAMS-22180

[a]University of Alaska Museum of the North identification number; [b]State Historic Preservation Office Alaska Historic Resources Survey number; [c]Stratigraphic relationship of sample to unofficially named tephras from the mSRV; [d]Material describes what was submitted to the University of Georgia Center for Applied Isotope Studies for dating; [e]Type refers to whether the sample was associated with cultural remains; [f]Provenience refers to the specific location the sample was obtained from; [g]Sample notes are those associated with the sample, given by original investigators; [h]Previous ^{14}C age years B.P. gives any related dates obtained as part of the Susitna Hydroelectric Project (1979–1985), which are associated with the same sample being re-dated as part of this project, or associated with the cultural component or stratigraphic location (original date lab numbers and UAMN accession identification of sample dated are given in parentheses); [i]Lab # refers to the lab number assigned by the University of Georgia Center for Applied Isotope Studies as part of this study.

Note: cmbs is cm below surface.

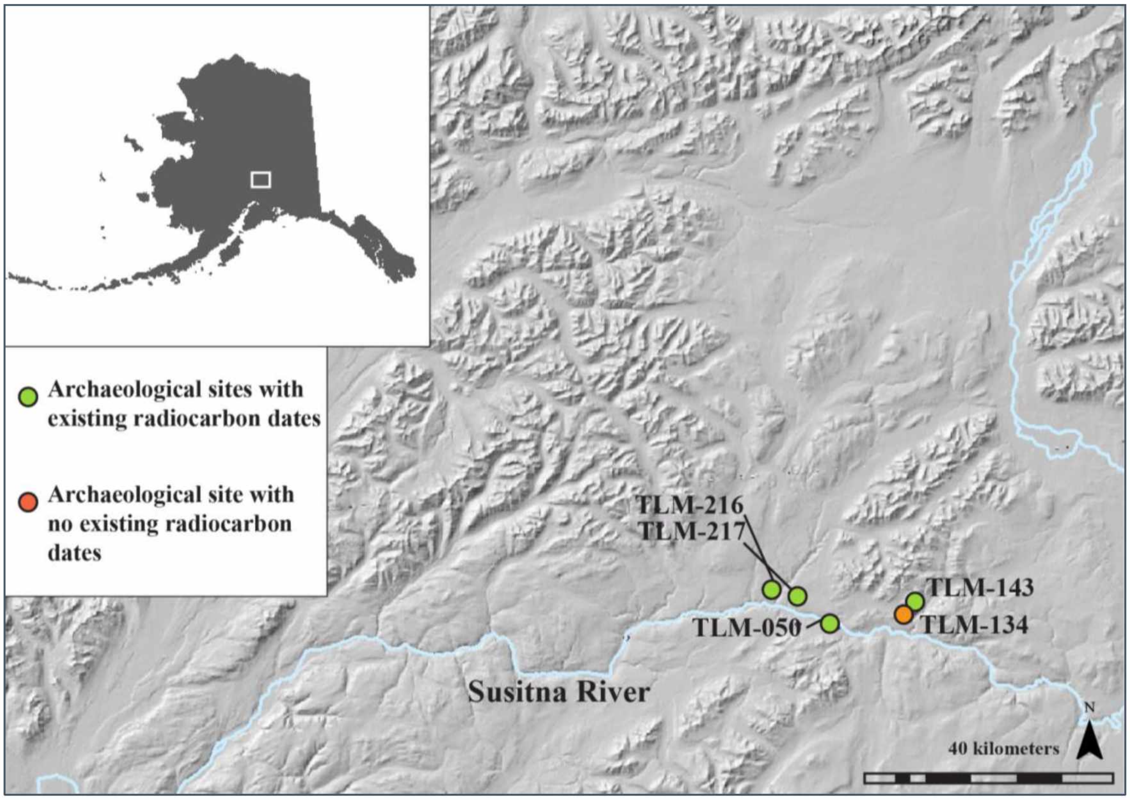


Figure 3.4. Archaeological sites in the mSRV with samples selected for dating as part of this study.

compared to dates produced via AMS for this study because the entire sample was consumed in radiometric dating during the 1980s. Therefore, AMS dates produced for this study are, in most cases, different charcoal fragments from the same bulk sample that produced a date in the 1980s, or a sample recovered from a close association. Sample number UA84-58-143a, b, c (UGAMS-22181) is an exception in that a relatively large piece of wood was collected from a cultural component between the Devil and Watana tephras at site TLM-216. Importantly, this sample is not a bulk sample but an isolated piece of spruce wood, used to produce multiple ^{14}C dates for the Susitna Hydroelectric Project (1979–1985). Two dates were initially produced from the piece of wood and had a wide range. The Susitna Hydroelectric report states, "The wide range of dates on a single piece of wood prompted the dating of additional fragments of the wood collected during survey testing" (Dixon et al. 1985:1386-1387), indicating an additional date was produced by a different sub-sample of the same piece of wood. This date further extended the range of dates associated with the piece of wood, which included: 1670±50 ^{14}C yr B.P. (Beta-9898), 1880±50 ^{14}C yr B.P. (Beta-9892), and 1530±80 ^{14}C yr B.P. (Beta-10125) (see Table 3.3, previous dates associated with site TLM-216). This sample is particularly important to the chronology of the mSRV because despite the wide range of dates produced from this single piece of wood, it was used as the maximum age limit of the deposition of the Devil tephra; therefore another sample was submitted for dating as part of this study to further refine the age estimate.

At archaeological site TLM-050, sample UA80-157-1 (UGAMS-22178) was selected for re-dating because of the large standard deviation associated with the original date (280±245 ^{14}C yr B.P., DIC-1904; Dixon et al. 1985), and because, as another occupation above the Devil, the date could be helpful for delimiting deposition of the Devil tephra. The individual charcoal specimen selected for AMS dating as part of this study came from the same bulk sample of charcoal that produced the original date associated with the component in the 1980s (DIC-1904).

Samples from two archaeological components bounding the Devil tephra at site TLM-217 were submitted for dating. The upper component occurs at the contact between the Devil tephra and the organic mat, and was originally dated as 2070±60 ^{14}C yr B.P. (Beta-9899; Dixon et al. 1985), which is problematically older than the maximum date for the deposition of the Devil tephra. In addition, the sample does not have a clear provenience. Therefore, another charcoal sample from the component above the Devil tephra at site TLM-217 was dated as part of this study; however, this charcoal sample came from a different bulk sample of charcoal, UA84-59-346 (UGAMS-22182), than that of the original date. The lower component at site TLM-217 occurs at the contact between the Watana and Devil tephra, and originally produced a date of 1770±190 ^{14}C yr B.P. (Beta-10791; Dixon et al. 1985). As opposed to the date from the upper component at this site, the date of the lower component is problematic because it has a very large standard deviation. Another charcoal sample from this lower component at site TLM-217 was therefore also submitted as part of this study, from bulk sample UA84-59-355 (UGAMS-22183), which is different than the bulk sample that produced the original 1980s date associated with component.

The lower component at TLM-143 (Jay Creek Mineral Lick), which occurs at the contact between the Watana and Oshetna tephras, was also selected for re-dating as part of this study. Dixon et al. (1985) attribute the lower component at TLM-143 to the Northern Archaic tradition (it contained notched points), and postulate that the site functioned as more than a hunting overlook owing to the wide range of tools in various stages of manufacture and thousands of flakes. Three dates of this component at Jay Creek Mineral Lick were produced as part of the Susitna Hydroelectric Project (1979–1985) (Dixon et al. 1985); however, although the dates produced by these samples overlap at 2 sigma, they all have relatively large standard deviations, approaching or greater than 100 years. Therefore, a new date is produced from the same bulk sample which produced the original date of 4440±120 ^{14}C yr B.P. (Beta-7698), UA82-83-1703 (UGAMS-22179).

The sixth radiocarbon sample is not cultural but was selected because of the stratigraphic location from which it originates. Sample UA82-74-4 (UGAMS-22180) does not have an associated date produced in the 1980s and is a stratigraphic date from archaeological site TLM-134. The sample was obtained from below the Oshetna tephra and therefore provides a modern AMS maximum date for the deposition of the Oshetna tephra.

3.2.2 Radiocarbon analyses

The six mSRV samples selected for ^{14}C analysis as part of this study were sent to the University of Georgia (UG) Center for Applied Isotope Studies for dating. ^{14}C is produced in the upper atmosphere when ^{14}N interacts with neutrons produced by cosmic rays (Ludwig and Renne 2000; Taylor 2000). $^{14}CO_2$ is distributed throughout the atmosphere and hydrosphere, allowing radioactive ^{14}C to become incorporated into living organisms, in addition to stable isotopes ^{12}C and ^{13}C, either through plant absorption or digestion of plants (Ludwig and Renne 2000; Taylor 2000). When ^{14}C ceases to become incorporated into an organism (i.e. when that organism dies), the isotope begins to radioactively decay with a half-life of 5730 years (Taylor 2000). Therefore, the ratio of the ^{14}C remaining to the constant stable isotope (^{12}C or ^{13}C) can be measured in anything created by a living organism, including wood, charcoal, shells, and seeds, and can be used to calculate when ^{14}C began to decay (i.e. when the organism ceased to be alive).

Before ^{14}C analysis, samples are pre-treated: extraneous (modern) carbon is separated from the sample and the fraction of the sample appropriate for dating is isolated by a combination of chemical or physical means (Cook and van der Plicht 2007). Whereas conventional radiometric analyses, which include liquid scintillation and gas proportional counting methods, literally count the number of ^{14}C decay particles, AMS directly measures the number of ^{14}C atoms relative to either ^{13}C or ^{12}C atoms in the sample, making the technique 1000 to 10,000 times more sensitive than conventional methods (Jull 2007). The advent of AMS in 1977 increased sensitivity and precision in ^{14}C analysis and allowed for dating of smaller samples; however, it was not available for wide application until later (Pettitt et al. 2003).

At the UG Center for Applied Isotope Studies, each charcoal sample was treated with 5% HCl at the temperature 80° C for one hour, and then washed with deionized water on the fiberglass filter and rinsed with diluted NaOH to remove possible contamination by humic acids. The sample was treated with diluted HCL again, washed with deionized water and dried at 60°C. For AMS analysis, the cleaned charcoal was combusted at 900°C in evacuated/sealed ampoules in the presence of CuO. The resulting carbon dioxide was cryogenically purified from the other reaction products and catalytically converted to graphite using the method of Vogel et al. (1984). Graphite $^{14}C/^{13}C$ ratios were measured using the CAIS 0.5 MeV accelerator mass spectrometer and sample ratios were compared to the ratio measured from the Oxalic Acid I (NBS SRM 4990). The sample $^{13}C/^{12}C$ ratios were measured separately using a stable isotope ratio mass spectrometer and expressed as $\delta^{13}C$ with respect to PDB, with an error of less than 0.1‰.

3.2.3 Methods of radiocarbon database construction

For this study, previously published ^{14}C dates, which are relevant to understanding the chronology of the mSRV, are compiled from archaeological and geological sources. The goals of compiling ^{14}C data are twofold: 1) to evaluate existing dates pertinent to the stratigraphy in the mSRV, and 2) to assimilate the appropriate and reliable dates for a refined chronology of the mSRV. The six new dates from the mSRV are obtained to aid in the evaluation and development of a robust chronology for this region.

There are number of issues associated with ^{14}C dates which should be considered, especially when compiling a large dataset. These include certainty of association, the old wood effect, contamination issues (related to sample age or sample type), inter-laboratory errors, issues with averaging, issues with interpreting large datasets, and calibration (Pettitt et al. 2003; Waterbolk 1971). Data for this analysis was gathered in an effort to address these issues, and when possible includes the laboratory that produced the date and the lab number, collector sample ID and site, material dated, provenience and context of the sample, stratigraphic location (with special reference to stratigraphic position relative to tephra), uncalibrated ^{14}C date and standard deviation (see supplemental excel file Mulliken_2016_thesis_supplemental, Table S2 for all compiled ^{14}C data). Some dates are associated with cultural components, whereas others are non-cultural, stratigraphic ages.

Criteria for accepting ^{14}C dates for inclusion in this study may be broadly outlined relative to the context, material dated, and laboratory. Context considerations include the certainty of stratigraphic association, which is checked for in dates associated with cultural materials by crosschecking provenience information with site reports and archaeological field notes. For stratigraphic dates, the location of the sample relative to the tephra unit in question is noted from publications. Contamination issues are addressed based on the material dated. The old wood effect is difficult to address without a ^{14}C date being anomalously old, and is complicated by a lack of published information on charcoal identification for archaeological ^{14}C samples from the mSRV. Any ^{14}C dates that were produced from bulk samples in the mSRV are not considered in this database, including ages produced from bulk organics, bulk peat, bulk cultural feature samples (e.g. multiple combined charcoal samples from a hearth), and samples with incorporation of matrix. In addition, those samples with standard deviations greater than 80 years are not considered in the database because the large calibrated age range of such dates complicates their use as stratigraphic age constraints. Consideration of the laboratories that produced ^{14}C dates were obtained is also critical and ^{14}C dates produced by Dicarb Laboratory are not considered as part of the database (see Section 2.4 for justification).

3.2.4 Radiocarbon database

Of the 68 ^{14}C dates obtained for the Susitna Hydroelectric Project (1979–1985; Dixon et al. 1985), re-evaluation based on the above criteria (Section 3.2.3) found only eight dates to be reliable for consideration in the chronology for this study. Five are from cultural components, at archaeological sites TLM-143, TLM-216 (three dates), and TLM-250, and three are stratigraphic dates from archaeological sites TLM-097 and TLM-184 (two dates) (Dixon et al. 1985), Wygal and Geobel (2012) also provide a date on a cultural component at the Susitna River Overlook site. Wendt (2013) provides two dates corresponding to two cultural components at the Butte Lake archaeological site. Bigelow et al. (2015) also provide three stratigraphic dates which meet the criteria for inclusion in this study. In addition, 19 new AMS dates are used in the mSRV chronology: six were funded through this study (Section 3.2.1), and 13 are previously unpublished AMS dates provided by the UAMN Archaeology Department (UAMN 2015). Consequently, a total of 33 ^{14}C dates, both cultural and stratigraphic, therefore contribute to the mSRV chronology (Figure 3.5; Table 3.4).

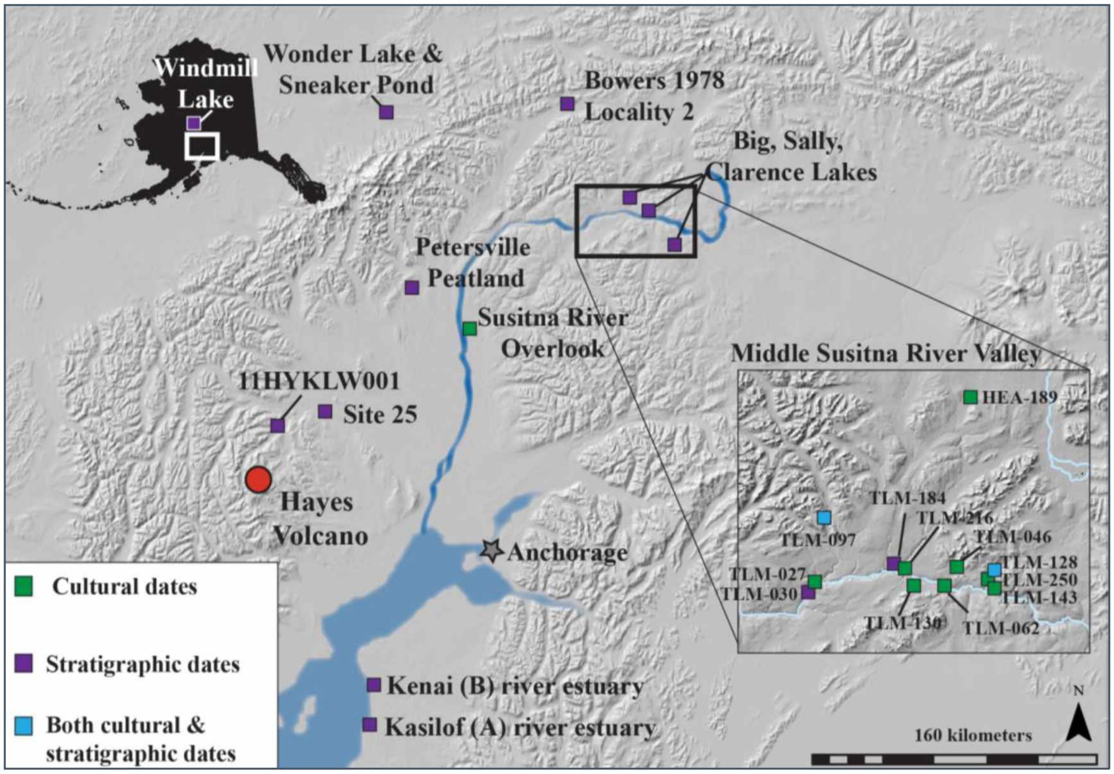


Figure 3.5. Localities with radiocarbon dates relevant to this study. See Table 3.4 for information on radiocarbon samples.

Eighteen dates from studies outside of the mSRV are also compiled to aid in evaluating the chronology of tephra-fall events (Figure 3.5; Table 3.4). Some of these dates were produced from bulk peat, and in some instances humic acid. Dating bulk peat is potentially problematic because if particles comprising the bulk are heterogeneous in age, the age will be an average of all particles and less meaningful for understanding and delimitingthe age of specific events. Humic acid has potential for contamination from organic material in the soil, which can result in dates that are younger than the targeted event. Despite these potentials for contamination, dates produced on these materials are used to evaluate the mSRV and ashfall events because they are considered in conjunction with dates on materials such as charcoal and plant fragments. Most dates have standard deviations of 80 years or less. In total, 51 dates are considered in this study, both from the mSRV and Cook Inlet area (including six dates produced as part of this study).

Table 3.4. Radiocarbon dates compiled from the mSRV and Cook Inlet, incorporated in this analysis. Continues onto next page.

Lab #[a]	Site[b]	Stratigraphic Location[c] Above Tephra	Below tephra	Material[d]	Type[e]	δ13C,‰[f]	^{14}C age, yr BP[g]	Calibrated median[h]	Calibrated age (2 δ)[i]	Reference[j]
Dates specific to the mSRV										
Beta-10798	TLM-250	Devil		Charcoal	Cultural	-	370±80	409	157–535	Dixon et al. 1985
Beta-7692	TLM-184	Devil		Charcoal	Stratigraphic	-	840±60	762	675–908	Dixon et al. 1985
Beta-7693	TLM-184	Devil		Charcoal	Stratigraphic	-	1060±70	980	798–1174	Dixon et al. 1985
Beta-7845	TLM-097	Devil		Charcoal	Stratigraphic	-	1260±80	1184	984–1305	Dixon et al. 1985
Beta-10125	TLM-216	Watana	Devil	Charcoal	Cultural	-	1530±80	1434	1293–1592	Dixon et al. 1985
Beta-9898	TLM-216	Watana	Devil	Charcoal	Cultural	-	1670±50	1578	1416–1705	Dixon et al. 1985
Beta-9892	TLM-216	Watana	Devil	Charcoal	Cultural	-	1880±50	1821	1703–1931	Dixon et al. 1985
Beta-5364	TLM-143	Oshetna	Watana	Charcoal	Cultural	-	4100±60	4628	4440–4824	Dixon et al. 1985
Beta-333868	HEA-189	Hayes		Charcoal	Cultural	-22.6	410±30	483	330–519	Wendt 2013
Beta-333870	HEA-189		Hayes	Charcoal	Cultural	-24.1	4220±30	4751	4644–4853	Wendt 2013
Beta-208284	Susitna River Overlook		Hayes	Charcoal	Cultural	-	8170±50	9116	9010–9267	Wygal and Goebel 2012
Beta-401550	TLM-097	Devil		Bone Collagen	Cultural	-18.1	140±30	143	6–281	UAMN Archaeology
UGAMS-22227	TLM-216	Watana	Devil	Bone Collagen	Cultural	-19.3	1540±20	1462	1376–1522	UAMN Archaeology
Beta-401548	TLM-130	Watana	Devil	Bone Collagen	Cultural	-19.2	1990±30	1940	1879–1997	UAMN Archaeology
UGAMS-22223	TLM-062	Devil		Charcoal	Cultural	-25.2	2240±20	2224	2158–2332	UAMN Archaeology
Beta-401547	TLM-030	Oshetna	Watana	Charcoal	Stratigraphic	-27	2390±30	2413	2346–2677	UAMN Archaeology
UGAMS-22226	TLM-184	Watana	Devil	Charcoal	Stratigraphic	-25.8	3170±20	3395	3363–3445	UAMN Archaeology
UGAMS-22225	TLM-046	Oshetna	Watana	Charcoal	Cultural	-24.7	3850±25	4269	4156–4406	UAMN Archaeology
UGAMS-19734	TLM-128	Oshetna	Watana	Charcoal	Stratigraphic	-23.2	3860±25	4288	4160–4409	UAMN Archaeology
UGAMS-18758	TLM-027	Oshetna	Watana	Charcoal	Cultural	-29.1	4070±25	4555	4441–4797	UAMN Archaeology
UGAMS-22224	TLM-097	Oshetna	Watana	Charcoal	Cultural	-24.2	4740±25	5521	5330–5583	UAMN Archaeology
Beta-401549	TLM-030	Oshetna	Watana	Charcoal	Stratigraphic	-27.3	5650±30	6432	6323–6495	UAMN Archaeology
Beta-147294	TLM-128		Oshetna	Charcoal	Cultural	-26.3	9600±60	10943	10746–11168	UAMN Archaeology
Beta-147295	TLM-128		Oshetna	Charcoal	Stratigraphic	-26	9790±60	11214	11094–11327	UAMN Archaeology
UGAMS-18849	Big Lake	Watana		Organics	Stratigraphic	-24	3200±30	3420	3366–3470	Bigelow et al. 2015
UGAMS-19730	Clarence Lake		Watana	Bark	Stratigraphic	-27.4	3690±25	4035	3929–4141	Bigelow et al. 2015
UGAMS-20053	Sally Lake		Watana	Pollen	Stratigraphic	-28.4	3740±20	4102	3991–4153	Bigelow et al. 2015

[a]Lab # designated by laboratory that conducted the ^{14}C analysis; [b]State Historic Preservation Office Alaska Historic Resources Survey number OR descriptive information on where the sample originated; [c]Designates where sample that produced the date came from, relative to informal tephra units; [d]Material describes what was submitted for dating; [e]Type refers to whether the sample was associated with cultural remains or not; [f]δ13C,‰ is the measured ratio of stable carbon isotopes, reported in parts per thousand, -not reported; [g]Radiocarbon date provided by laboratory; [h]Calibrated median and [i]Calibrated age range to two standard deviations determined using the IntCal13 terrestrial calibration curve in the CALIB Program, version 7.1 (Reimer et al. 2013; Stuiver and Reimer 1993); [j]Reference that the date was acquired from.

Note that the six samples dated as part of this project are not included in this table.

Table 3.4. Radiocarbon dates compiled from the mSRV and Cook Inlet, incorporated in this analysis. Continued from previous page.

Lab #[a]	Site[b]	Stratigraphic Location[c] Above Tephra	Below tephra	Material[d]	Type[e]	δ13C,‰[f]	^{14}C age, yr BP[g]	Calibrated median[h]	Calibrated age (2 δ)[i]	Reference[j]
Dates from Cook Inlet area, significant to evaluating tephra fall events										
CAMS-12291	Sneaker Pond Core-SP16		FT1(Hayes)	Plant Fragments	Stratigraphic	-	3830±60	4239	4013–4507	Child et al. 1998
CAMS-15637	Wonder Lake Core-WL9	FT-2 (Oshetna)		Plant Remains	Stratigraphic	-	5850±60	6664	6497–6791	Child et al. 1998
CAMS-15642	Wonder Lake Core-WL9		FT-2 (Oshetna)	Plant Remains	Stratigraphic	-	6020±60	6865	6679–7144	Child et al. 1998
CAMS-12292	Sneaker Pond Core-SP16		FT-2 (Oshetna)	Plant Fragments	Stratigraphic	-	6060±60	6918	6750–7056	Child et al. 1998
Beta-45204	Kenai Peat Deposits, Site A	AT1 (Hayes)		Wood	Stratigraphic	-	3470±70	3743	3568–3911	Combellick and Pinney 1995
Beta-50332	Kenai Peat Deposits, Site A		AT1 (Hayes)	Bulk Peat	Stratigraphic	-	3510±60	3783	3636–3963	Combellick and Pinney 1995
Beta-50336	Kenai Peat Deposits, Site B		BT1(Hayes)	Bulk Peat	Stratigraphic	-	3540±70	3825	3638–4066	Combellick and Pinney 1995
Beta-45210	Kenai Peat Deposits, Site B	BT1(Hayes)		Wood	Stratigraphic	-	3590±70	3896	3701–4085	Combellick and Pinney 1995
UCIAMS-77137	Petersville Peatland Core PE-09-90	Hayes		Root-Free Bulk Peat	Stratigraphic	-	3020±15	3210	3164–3324	Loisel et al. 2013
UCIAMS-81451	Petersville Peatland Core PE-09-450	Hayes		Root-Free Bulk Peat	Stratigraphic	-	3405±35	3653	3568–3818	Loisel et al. 2013
UCIAMS-81453	Petersville Peatland Core PE-09-200	Hayes		Root-Free Bulk Peat	Stratigraphic	-	3685±20	4037	3932–4088	Loisel et al. 2013
Georgia-13293	Hayes River Outcrop-11HYKLW001	Tephra A	Tephra B	Humic Acid	Stratigraphic	-26	3690±30	4033	3926–4144	Wallace et al. 2014
Georgia-13292	Hayes River Outcrop-11HYKLW001	Tephra A	Tephra B	Humic Acid	Stratigraphic	-27.3	3750±30	4113	3987–4229	Wallace et al. 2014
I-12250	Sampling Locality 25	Hayes set	Tephra 27-A (younger than Hayes set)	Organic bearing silt, rare white rootlets	stratigraphic	-	1860±80	1791	1605–1987	Riehle 1985
I-33357	Sampling Locality 14	Hayes set		Peat (twigs, leaves)	stratigraphic		3520±90	3799	3575–4078	Riehle 1985
I-33356	Sampling Locality 14	Hayes set		Peat (twigs, leaves)	stratigraphic		3500±90	3776	3562–4071	Riehle 1985
WSU 1747	Central Alaskan Range, locality 2		Cantwell Ash	Bulk Peat	Stratigraphic	-	3780±80	4164	3930–4413	Bowers 1978
CAMS-22019	Windmill Lake		Jarvis Creek Ash	Seed	Stratigraphic	-	3690±70	4031	3843–4235	Bigelow and Edwards 2001

[a]Lab # designated by laboratory that conducted the ^{14}C analysis; [b]State Historic Preservation Office Alaska Historic Resources Survey number OR descriptive information on where the sample originated; [c]Designates where sample that produced the date came from, relative to informal tephra units; [d]Material describes what was submitted for dating; [e]Type refers to whether the sample was associated with cultural remains or not; [f]δ13C,‰ is the measured ratio of stable carbon isotopes, reported in parts per thousand, -not reported; [g]Radiocarbon date provided by laboratory; ; [h]Calibrated median and [i]Calibrated age range to two standard deviations determined using the IntCal13 terrestrial calibration curve in the CALIB Program, version 7.1 (Reimer et al. 2013; Stuiver and Reimer 1993); [j]Reference that the date was acquired from.

Note that the six samples dated as part of this project are not included in this table.

3.2.5 Radiocarbon data calibration

The amount of ^{14}C in an organism is roughly equivalent to atmospheric concentrations; however, because cosmic radiation and the intensity of Earth's magnetic field (which affects the influx of solar radiation) have not been constant through time, the technique requires calibration. Prior to calibration, ^{14}C dates are usually reported as mean years "before present" or B.P. (present being measured prior to 1950), with one standard deviation uncertainties (van der Plicht and Hogg 2006). The ^{14}C age range is then compared to a calibration curve to produce a calibrated age range where the ^{14}C age range intercepts the calibration curve, reported to either one or two standard deviations (Reimer and Reimer 2007). The intercept reported is where the mean of the ^{14}C date intercepts the calibration curve; however, this does not consider the distribution of the uncalibrated ^{14}C age relative to the calibration curve and the relative probabilities of a ^{14}C date that intercepts the calibration curve in multiple areas (Reimer and Reimer 2007). A weighted average or median has been recommended instead (Telford et al. 2004). All uncalibrated ^{14}C dates considered in this study are calibrated using the IntCal13 terrestrial calibration curve in the CALIB Program, version 7.1 (Reimer et al. 2013; Stuiver and Reimer 1993). Bayesian statistical methods have also recently been employed to aid in calibration, and are used in this analysis.

3.2.5.1 Bayesian age models

Bayesian age models offer a statistical means for which to evaluate ^{14}C dates. The key characteristic of Bayesian models is the incorporation of prior information, which may be converted into a prior probability that contributes to evaluation of the data and generation of posterior probabilities (Buck et al. 1996). For example, stratigraphic information about where samples came from may be incorporated into the parameters of a Bayesian model and the posterior probability generated expresses these data in light of the prior information that is incorporated. Bayes' theorem is given below (Equation 2, from Bronk Ramsey 2009a).

Oxcal 4.2 (online version) and the IntCal13 terrestrial calibration curve are used for Bayesian calibration (Bronk Ramsey 2008; Bronk Ramsey 2009a, 2009b; Reimer et al. 2013). Dates produced from the same piece of wood at TLM-216 (Section 3.2.1) are evaluated using the R_combine tool, which considers dates that should relate to the same event. In this case, samples from a single piece of wood, located between the Devil and upper oxidized Watana tephras at

TLM-216, were submitted three times for dating as part of the Susitna Hydroelectric Project (1979–1985) and once more in this study, with a wide range of results. All results are evaluated using the R_combine tool to determine a maximum probability age of the sample, which is useful for delimiting the age of the Devil tephra.

Equation (2): Bayes' Theorem

$$P(t/y) \propto P(y/t)\, P(t)$$

where:

t = set of parameters
y = observations or measurements made
$p(t)$ = prior, information about measurements independent of measurements
$p(y/t)$ = likelihood for the measurements given a set of parameters
$p(t/y)$ = posterior probability: probability of particular parameter set given the measurements and the prior

Because information gathered for this analysis includes both relative stratigraphic position of samples used for ^{14}C dating, and the absolute ages produced by the samples, a Bayesian model of calibration is also used to constrain the timing of specific stratigraphic events. Stratigraphic position of a sample may be incorporated into the model (prior probability), in order to evaluate the absolute ages produced by these samples and the events they are being used to constrain. The sequence tool is used within Oxcal 4.2, which allows for consideration of dates associated with events that occur in a specific, correct order, but without consideration of the stratigraphic depth of the sample (Bronk Ramsey 2008). This is ideal because dates from various locations are incorporated into the model, in order to better evaluate the timing of the ashfall events.

In modeling the ages of tephra deposition, dates derived from a location stratigraphically below or above a tephra are viewed as belonging to a specific phase, defined using the tau_boundary and phase commands in Oxcal 4.2 (e.g. Petrie and Torrence 2008; Vandergoes et al. 2013). The tau_boundary command assumes that there is a maximum event probability at a certain location in the model (that the user designates). The phase tool assumes that all events within the phase are equally likely to occur somewhere within the start and end boundaries (defined by the earliest and latest dates), with no information about the order in which they should occur (Bronk Ramsey 2009a). This is ideal because multiple dates from a particular stratigraphic location at multiple geographic locations are considered. A multiple phase model is built with the stipulation that some phases should come after the ends of others, e.g. a phase consisting of ^{14}C dates obtained from above tephra A should come after a phase consisting of ^{14}C dates obtained from below tephra A. The ^{14}C dates within each stratigraphic group are then used to develop a maximum probability age of the deposition of that tephra.

3.3 Analysis of archaeological materials

Archaeological materials from the mSRV were collected and summarized in site reports as part of the Susitna Hydroelectric Project (1979–1985) (Dixon et al. 1985). The documentation of material from the mSRV offers a means to analyze coarse trends in archaeological component characteristics through time, particularly as they relate to established trends in interior Alaskan archaeology, and to ashfall events. This section summarizes how the archaeological database was created from the Susitna Hydroelectric Project (1979–1985) report (Dixon et al. 1985), and the analyses that were undertaken with that database.

3.3.1 Creating the mSRV site database

A database of mSRV archaeological sites was created to allow for coarse-grained analysis of archaeological components in the mSRV through time (designed after Potter 2008a, 2008c). Site information was gathered from the Susitna Hydroelectric Report (1979–1985) (Dixon et al. 1985) and component delineation, artifact classifications, and other site data given in that report are assumed to be accurate. Sites incorporated into the database are those that have stratigraphic integrity, with defined tephra units and well-defined stratigraphic locations of artifacts relative to tephras. Archaeological sites located on blowouts, deflated areas, eroded areas, bedrock outcroppings, and mineral licks were not incorporated into the database because of the inability to date the cultural materials relatively.

3.3.2 Variables considered

The selected variables are those that have proven useful in previous analyses of inter-site variability in interior Alaskan prehistory, particularly those that relate to land use and mobility strategies, subsistence, the use of storage facilities, and specific assemblage characteristics (Potter 2008a, 2008c). The following variables were collected for each archaeological component: total number of lithic materials (debitage + tools), number of tools, number of tool classes, presence of specific lithic types (microblades and microblade cores, notched points, projectile points), presence of faunal remains, classes of faunal remains (and species if available), presence of cultural depressions (indicative of structures or storage facilities), and the nature of the landform upon which the archaeological site is located. Measured variables include lithic artifact density (defined as the number of lithic artifacts divided by the area excavated in m^2), richness of the lithic assemblage (defined as the number of lithic artifact classes present), and evenness of the lithic assemblage (uniformity of the assemblage). Evenness of the lithic artifact assemblage is calculated using a diversity index (Equation 3), which is defined below from Adrefsky (2005). Richness and evenness have been explored relative to mobility and the frequency of moves a hunter-gatherer group makes per year, as well as the type of residence that a site represents (Andrefsky 2005).

Equation (3): Evenness

$$E = \frac{(\frac{n_i}{n})(\log \frac{n_i}{n})}{\log s}$$

Where:

n_i = the number of artifacts for each type
n = the number of artifacts for all types
s = the number of artifact types

The stratigraphic location of archaeological material is used to separate archaeological components into independent groups that are bounded by or within tephra units. Independent groups are coded according to the following stratigraphic locations: pre-Oshetna, within Oshetna, between Oshetna and Watana, within Watana, between Watana and Devil, within Devil, and above Devil tephras. However, only those stratigraphic groups bounded by tephra units are considered for statistical analyses because components within tephra units cannot be confidently evaluated as to their timing relative to the tephra. Indeed, cultural components occurring within tephra units could also result from cryoturbation, or other disturbances.

3.3.3 Analyses of archaeological sites in the mSRV

Non-parametric statistical tests are employed because of the limitations posed by small sample sizes in some of the stratigraphic groups of archaeological component data and the inability of the data to meet assumptions of normality. Potter (2008c) has demonstrated the use of the Pearson chi-square statistic, Fisher's Exact test, and Cramer's V for exploring the variation in archaeological components through time. Therefore, these statistical measures are used in this analysis, and are performed using IBM SPSS Statistics 22 analytical software. Categorical variables (presence of specific lithic types and landform sites are located on) are tested for association in independent stratigraphic groups using the Pearson chi-square test. The Pearson chi-square statistic tests the null hypothesis that population means between two independent samples are equal. The Fisher's Exact test measures the statistical significance of differences in sample means conservatively and Cramer's V provides a measure of the association between variables (Norušis 2012).

In addition to statistical analyses, archaeological site variables are considered relative to the current understanding of prehistory in central interior Alaska. Presence of faunal remains, classes of faunal remains (and species if available), presence of lithic types, lithic artifact density, richness of the lithic assemblage (defined as the number of lithic artifact classes present), and evenness of the lithic assemblage are qualitatively evaluated relative to established trends in central interior Alaskan archaeology.

3.4 Qualitative model building for understanding effects of tephra deposition

This research relies on incorporating analogy for proposing potential environmental effects of tephra deposition in the mSRV, with special attention to hunter-gatherer subsistence resources. The effects of tephra deposition vary depending on the deposit and the environment; however, because specific effects of tephra deposition in the mSRV have not been investigated, analogy offers a means by which potential environmental effects of tephra deposition in the mSRV may be conservatively extrapolated. The effects of some explosive volcanic events in historical times have been documented closely, allowing for these events to be used, similar to ethnographic analogies that inform interpretation of archaeological remains, in an attempt to understand the potential effects of prehistoric eruptions on the environment and upon prehistoric populations.

Data on the effects of historic plinian eruptions, including the 1980 eruption of Mount St. Helens and the 1912 eruption of Novarupta-Katmai, are collected. Documentation of the effects of these events has contributed greatly to understanding how the environment may be changed as a result of the volcanic events, and how it continues to change for decades afterward (Antos and Zobel 2005; Hildreth and Fierstein 2012). Information is gathered regarding the size of these eruptive events, the timing of the eruption (season), the distribution of the ash, the thickness of ash deposits, plant species that did and did not survive tephra deposition (with reference to tephra thickness), whether or not snow was present or absent, and the length of time required for vegetation recovery as well as the type(s) of plant colonization on tephra surfaces. Various other information considered relevant for understanding potential effects of ash deposition in the mSRV is also gathered, such as information on the direct impacts of volcanic ash to animals, including people.

Archaeological research often relies on ethnographic analogy, drawing on knowledge of the subsistence economies and toolsets of historic populations to make connections and inferences of behavior from archaeological material remains. Although analogy is often criticized as not being appropriate for scientific research, its application in archaeological contexts can be constructive and legitimate, provided the limitations are recognized and the research questions are posed in a theoretically relevant framework (Wylie 1985). Ethnographic information on the seasonality and subsistence patterns of groups using the mSRV during historical times is gathered in an effort to understand how tephra deposition may have affected hunter-gatherer resources in mSRV. Information gathered includes the territorial areas and boundaries, as well as the season and location that subsistence resources were typically obtained. However, settlement systems, subsistence economies and land use patterns in interior Alaska are marked by significant shifts in the mid and late Holocene (Esdale 2008; Potter 2008c). Because ash deposition occurred at different times in the mSRV, and therefore during times of different and distinct settlement and subsistence systems, information on resource exploitation and mobility patterns throughout the Holocene in central interior Alaska is also incorporated.

Data on the effects of tephra deposition are integrated with information on the preservation of tephra units in the mSRV (thickness of the deposit, occurrence), and its physiography with attention to potential for weathering of the tephra unit after deposition. In conjunction with data on successional processes in Alaska, this information is integrated to qualitatively model how tephra deposition would have affected the mSRV environment depending on the season of deposition, and to consider what the implications of tephra deposition on both plant and animal resources could have been.

3.5 Theoretical approach: Human behavioral ecology

Theory has evolved within archaeology as a means to explain and understand cultural behavior and different theoretical approaches have different assumptions and offer differ mechanisms and means of explanation. This study will interpret results within the theoretical framework of human behavioral ecology (HBE). HBE is a framework in anthropology for evaluating and explaining the patterns of behavioral diversity among hunter-gatherers, as they relate to the function and adaptive value of the behaviors in a specific and/or environmental context (Bird and O'Connell 2006, 2012; Winterhalder and Smith 2000). HBE borrows conceptual frameworks from the biological sciences and economics and posits that human behavior may be understood under the same assumptions and using the same techniques that are used to study the behaviors of other animals (Joseph 2000).

Models within HBE consider the decision-making process of individuals in terms of costs and benefits. Variations within the environment, cultural factors, and individual phenotypes all affect the options that are available within a particular context (Smith and Winterhalder 1992). Within HBE, cultural inheritance is considered to be analogous to genetic inheritance because cultural traits and information are transmitted and may be subject to natural selection (Kelly 2013). Although this study does not apply specific HBE models, it considers generalizations about hunter-gatherer behavior predicted by the models. Tephra deposition occurs over a relatively short period of time, but can have extreme effects on the environment and therefore the resources available to hunter-gatherers. HBE models are employed as a means to predict potential hunter-gatherer behavior in response to changes in the environment caused by ash deposition.

3.5.1 Optimal foraging theory and patch choice models

A major area of concern within HBE is that of resource acquisition. Although hunter-gatherer subsistence strategies vary greatly, this approach seeks to use models as a means to understand and explain different foraging strategies (Winterhalder 2001). Optimal foraging theory describes a set of models within HBE that focus on hunter-gatherer resource selection, time allocation, and habitat and patch choice (Winderhalder and Smith 2000). Environmental factors are considered in order to derive predictions in foraging behavior and resource selection as a result of changes in the environment or forager capacities (Winterhalder 2001).

Optimal foraging theories assume that human behaviors that relate to subsistence, including diet choice, foraging location, time, group size, and settlement location, are adaptive and decisions are made to maximize net rate of energy gain; i.e. how to obtain food resources most efficiently (Bettinger 1991; Kelly 2013; Smith 1987; Winterhalder and Smith 2000). Therefore, if foragers are assumed to behave in ways that maximize the net rate of energy gain, models may provide predictions as to what behaviors may be expected in particular ecological contexts. Relationships between specific key variables, such as resource density and diet breadth, are investigated under the assumption that individuals will behave in fitness-enhancing, optimal ways (Gremillion 2002). One common model within optimal foraging theory is the patch choice model.

Patch choice models consider behavior in terms of the optimal habitat being exploited (MacArthur and Pianka 1966; Smith 1983). These models acknowledge that environments do not consist of homogenously distributed resources, but rather are a discontinuous mosaic of heterogeneous, or patchily distributed, resources (Winterhalder 1981). Patch size does not have to be consistent, but rather patches may be conceptualized as a hierarchy or mosaic of patches that may overlap and occur over varying spatial scales (Kotliar and Wiens 1990). What ultimately delineates a patch are the resources available within it, including plants and animals (Wiens 1976). Patch boundaries may not be distinct, but rather gradual and related to abundance and availability of certain resources. How organisms respond to variations in patch size and frequency on the landscape may also be considered and vegetation patterns may dictate the spatial availability of other terrestrial resources on the landscape. Therefore, fundamental choices regarding optimization of patch choice are which patches an individual should choose to forage in and how long an individual should forage in each patch before moving on to a new one (Smith 1983).

Applications of the patch choice model assume that the forager ranks patches with respect to the energy available within them and the time it takes to acquire that energy, i.e. the net rate of energy intake per unit of foraging time (Bettinger 1991). Although higher ranked patches produce the best energy return per unit of foraging time, they may be far apart. Travel time between patches is potentially a constraining factor, as patches may be separated by intervening space devoid of desirable resources (Bettinger 1991; Smith 1983; Winterhalder 2001). Therefore, a greater number of lower ranked patches may be incorporated in to the foraging schedule, excepting those patches with return rates less than that of the overall habitat return rate.

Patch choice models allow for hypothesis testing regarding resource abundance and acquisition in a patchy environment; for example, with decreasing resource abundance, a wider range of patches may be included in the foraging itinerary, suggesting a shift from patch specialization to generalization (Bettinger 1991). Increasing the number of patches that are foraged in may decrease the selectivity of patches included in the foraging itinerary. Changes in patch selection and exploitation patterns, therefore, may have implications on the types of resources acquired, as well as mobility patterns, both of which are sometimes determinable archaeologically.

3.5.2 Constraints: resources, mobility, and risk

Winterhalder (2001) emphasizes that hunter-gatherers are defined by their economy, which is often influenced by resources available in the environment. Mobility, which is defined as the nature of hunter-gatherer movements across a landscape, is also a characteristic of hunter-gatherers that is profoundly influenced by resources and the environment (Kelly 1983). Understanding the ecological context of a hunter-gatherer society may therefore be critical to understanding the subsistence and mobility strategies, both of which may be constrained by patterns of resource availability on the landscape.

Mobility varies over different spatial and temporal scales (Binford 1990; Johnson 2014; Kelly 1992). It may be measured in terms of the number of moves per year, or even per season, the duration of occupation, distance covered in each individual move, or total distance covered over an entire year. Binford (1980) distinguishes between foragers and collectors, for example, as occupying opposite poles of subsistence/settlement hunter-gatherer adaptations, between which are a range of variations. Foragers are those hunter-gatherers who inhabit patchy environments, and are therefore dependent on resources within patches; resource variation in patches dictates the number of residential moves and size of the group. For relatively homogenous and rich patches, the number of moves will be greater, but with less distance between than if the patches are less rich and homogenous, which will also result in a smaller foraging group. Alternatively, collectors may also inhabit patchy environments, but rely more on specific, critical resources obtained via logistical forays from the residential location. The residential location may also be dependent upon maximizing the efficiency of logistical foraging opportunities. Binford (1980) emphasizes that the greater the seasonal variation in temperature (and therefore resource availability), the more likely a hunter-gatherer group will be logistically oriented and employ food storage strategies. However, food storage does not absolutely imply logistical mobility patterns.

Mobility can be interpreted as a risk-avoidance strategy in that as patches are depleted during resource acquisition, hunter-gatherers will be more likely to obtain resources from another patch and thus decrease risk by moving to a new patch; however, because hunter-gatherers are not omniscient as to where resources are on the landscape and at what specific times, mobility in and of itself also entails risk (Kelly 2013). Thus, within the HBE framework, mobility has both costs and benefits, which must be evaluated relative to risk.

3.6 Summary

This chapter has provided information on the specific materials considered as part of this study, and the methods used to analyze them. Despite previous tephra and ^{14}C analyses completed as part of the Susitna Hydroelectric Project (1979–1985) (Dixon et al. 1985), advances in both techniques merit further study. In addition, characterization of proximal Hayes Volcano reference tephra allows for direct comparison of the mSRV tephra samples for potential correlation. With archaeological components at all levels of the stratigraphy, the mSRV offers a unique opportunity to examine variation in archaeological components that are bounded by tephra units, relative to cultural component dates and assemblage characteristics. Grouped archaeological components separated by tephra units allow for testing of differences in assemblage characteristics at stratigraphic locations, specifically as they relate to established trends in archaeological assemblages through time in interior Alaska (Esdale 2008; Potter 2008c).

Because volcanic events have the potential to drastically alter an environment utilized by hunter-gatherers, environmental effects of tephra deposition in the mSRV are considered using information from other volcanic events, with particular attention as to how events may have affected resource availability in the mSRV. Existing models for understanding subsistence and settlement variation through time in the archaeological record of interior Alaska also offer a means from which to predict the resources exploited in the mSRV during the timeframe of each tephra deposition and optimal foraging theory and patch choice models may be used to dictate potential hunter-gatherer response to tephra deposition, within the parameters of current understanding of hunter-gatherer behavior in interior Alaska at different time periods. The results of tephra, radiocarbon, and archaeological analyses are presented in Chapter 4. Chapter 5 presents information on other volcanic events and their effects in an attempt to model the effects of tephra deposition on the environment of the mSRV, with particular attention to resources exploited by hunter-gatherers. The results of all analyses and model building are integrated and discussed in Chapter 6.

Chapter 4: Results

This chapter summarizes the results of tephra, radiocarbon, and archaeological analyses completed as part of this study. The chapter is divided into three sections: Section 4.1 describes the results of the EPMA of tephra and similarity coefficient calculations between tephra samples; Section 4.2 details the results of AMS radiocarbon analyses and revising the chronology of the mSRV; and, Section 4.3 summarizes the results of analyses of archaeological variables by stratigraphic position.

4.1 Tephra analyses

This section summarizes the results of tephra analyses and is divided into three subsections: Subsection 4.1.1 describes the results of EPMA of tephra; Subsection 4.1.2 details the results of similarity coefficient calculations; and, Subsection 4.1.3 summarizes the results of geochemical analyses and similarity coefficients for tephra correlation purposes.

4.1.1 Results of EPMA of tephra

Results of EPMA geochemical analyses of all tephra are given as individual point data and averages in the supplementary file that accompanies this thesis (Table S3 and S4 in Mulliken_2016_thesis_supplemental). Results in this section are addressed with regard to populations of glass composition identified within each mSRV reference tephra unit. Within this section, tables for relevant reference tephra samples may be referenced for the number of individual points within each population of glass, and the standard deviation (reported to 1 σ) for each oxide within each population.

4.1.1.1 Middle Susitna River Valley reference archaeological tephra

Results of analyses for each archaeological reference tephra at site TLM-027 (AT-3184 through AT-3188) are given as glass population averages with standard deviations in Table 4.1; total alkalis versus silica are plotted in Figure 4.1. The Devil reference tephra (AT-3184) appears to be homogenous with a single population of volcanic glass with an average of 73 weight percent SiO_2. The three subsamples of Watana reference tephra came from the uppermost black to reddish brown portion of the tephra (AT-3185), the strong brown mid-deposit oxidized zone

Table 4.1. Major-oxide glass compositions of archaeological reference tephra from sites TLM-027 and TLM-128, determined by electron probe microanalyzer at the University of Alaska Fairbanks Advanced Instrumentation Laboratory.

Sample Name[a]	AT-#[b]	Unit[c]		SiO_2	TiO_2	Al_2O_3	FeO_T	MnO	MgO	CaO	Na_2O	K_2O	Cl	P_2O_5	$TOTAL_{raw}$	n
TLM-027-4 (UA81-243-0491)	AT-3184	Devil	mean	73.21	0.27	14.38	1.80	0.07	0.53	2.59	4.12	2.54	0.45	0.10	97.62	44
			1 δ	*0.81*	*0.06*	*0.33*	*0.21*	*0.04*	*0.10*	*0.27*	*0.27*	*0.08*	*0.08*	*0.13*	*1.13*	
TLM-027-5 (UA81-243-0491)	AT-3185	Uppermost Oxidized Watana	mean	73.81	0.24	14.27	1.68	0.09	0.50	2.43	4.09	2.56	0.35	0.04	97.90	20
			1 δ	*0.57*	*0.03*	*0.22*	*0.16*	*0.05*	*0.04*	*0.16*	*0.14*	*0.06*	*0.04*	*0.07*	*0.64*	
TLM-027-6 (UA81-243-0491)	AT-3186	Oxidized Watana	mean	73.45	0.24	14.52	1.69	0.07	0.50	2.54	4.10	2.52	0.36	0.06	97.20	21
			1 δ	*0.75*	*0.03*	*0.45*	*0.13*	*0.04*	*0.04*	*0.23*	*0.22*	*0.13*	*0.03*	*0.09*	*0.90*	
TLM-128 (UA82-068)	AT-3444-P1	Unoxidized Watana	mean	73.60	0.25	14.28	1.72	0.09	0.51	2.52	4.07	2.57	0.38	0.09	98.70	22
			1 δ	*0.39*	*0.02*	*0.20*	*0.12*	*0.03*	*0.04*	*0.09*	*0.17*	*0.06*	*0.04*	*0.09*	*0.47*	
	AT-3444-P2			66.78	0.20	18.33	1.75	0.05	0.75	5.56	4.62	1.65	0.19	0.15	100.00	1
TLM-027-8 (UA81-243-0491)	AT-3188-P1	Oshetna	mean	74.11	0.46	13.00	2.17	0.07	0.41	2.14	4.18	3.05	0.43	0.03	97.38	11
			1 δ	*0.28*	*0.04*	*0.24*	*0.10*	*0.05*	*0.09*	*0.30*	*0.60*	*0.92*	*0.22*	*0.11*	*1.36*	
	AT-3188-P2		mean	68.11	0.67	15.10	3.82	0.13	1.05	3.68	4.58	2.42	0.22	0.24	98.53	9
			1 δ	*0.54*	*0.27*	*0.55*	*0.52*	*0.06*	*0.12*	*0.37*	*0.21*	*0.46*	*0.03*	*0.16*	*1.23*	
	AT-3188-P3		mean	71.08	0.62	14.00	3.16	0.11	0.82	3.26	4.51	2.09	0.25	0.14	98.91	7
			1 δ	*0.65*	*0.20*	*0.68*	*0.56*	*0.06*	*0.10*	*0.31*	*0.12*	*0.24*	*0.03*	*0.07*	*0.30*	
	AT-3188-P4		mean	78.22	0.29	11.95	1.32	0.01	0.21	1.48	4.24	2.14	0.14	0.02	95.87	5
			1 δ	*0.82*	*0.06*	*0.47*	*0.12*	*0.02*	*0.11*	*0.59*	*0.70*	*1.08*	*0.06*	*0.08*	*0.57*	

[a]State Historic Preservation Office Alaska Historic Resources Survey number, University of Alaska Museum of the North identification in parentheses; [b]Alaska Tephra Laboratory and Data Center identification number (AT #); [c]Unit refers to unofficially named tephras from the mSRV.
Reported compositions are weight percent averages of n points, normalized to 100 percent; total gives original sum, 1 σ is standard deviation, not standard deviation of the mean. Raw point data given in supplemental file. P-, population; raw, original raw total.

(AT-3186), and the lower yellowish brown unoxidized portion (AT-3187) (see Figure 3.3). The upper and middle sub-samples of the Watana tephra (AT-3185 and AT-3186, respectively) appear to have a single population of volcanic glass averaging 73 weight percent SiO_2.

Analyses of the lower yellowish brown unoxidized portion of the Watana reference tephra (AT-3187) were unsuccessful due to low oxide totals. Therefore, a sample of the unoxidized portion of the Watana tephra from another archaeological site, TLM-128 (see Figure 3.1) is used as an alternate reference (AT-3444, see Appendix A for sample description). This sample is geochemically very similar to the upper two oxidized subsamples of the Watana at site TLM-027, with a primarily glass composition of 73 weight percent SiO_2; however, a single analysis with a lower composition (66 weight percent SiO2) is also present. Analyses of the reference Oshetna tephra (AT-3188) reveal the presence of four populations of volcanic glass ranging from 68–78 weight percent SiO2.

4.1.1.2 Other mSRV archaeological tephra from informal tephra units

Five other Devil tephra samples from the mSRV, in addition to the Devil reference tephra sample (AT-3184), were analyzed to capture variation throughout the deposit. Average glass population compositions are shown in Table 4.2. Notably, all Devil tephra samples contain a primary population of glass with an average between 73–74% SiO_2; however, three of the samples (AT-3194, AT-3205, and AT-3445) also contain minor populations. Sample AT-3194 contains three sub-populations of volcanic glass: 67, 70, and 77 weight percent SiO_2. Sample AT-3205 contains two minor populations of volcanic glass, averaging 69 and 70 weight percent SiO_2 (differences in other oxide weight percents suggest the two are independent). Lastly, sample AT-3445 contains a single point, with a composition of 69 weight percent SiO_2 that differs from the primary volcanic glass population composition.

Eight other Watana tephra samples were analyzed in addition to the Watana reference tephra samples in order to evaluate any compositional variation not observed in the reference tephra (AT-3185, AT-3186, and AT-3444). Average glass compositions are shown in Table 4.3. All samples have a primary glass composition of 72–73 weight percent SiO_2. Four samples also contain minor sub-populations of volcanic glass. Note, however, other than sample AT-3448, the original sample collectors did not indicate whether the samples were collected from the oxidized or unoxidized portion of the Watana tephra. AT-3195 contains two minor sub-populations of

Table 4.2. Major-oxide glass compositions of archaeological Devil tephra, determined by electron probe microanalyzer at the University of Alaska Fairbanks Advanced Instrumentation Laboratory.

Sample Name[a]	AT-#[b]	Unit[c]		SiO_2	TiO_2	Al_2O_3	FeO_T	MnO	MgO	CaO	Na_2O	K_2O	Cl	P_2O_5	$TOTAL_{raw}$	n
TLM-027-4 (UA81-243-0491)	AT-3184	Devil	mean	73.21	0.27	14.38	1.80	0.07	0.53	2.59	4.12	2.54	0.45	0.10	97.62	44
			1 δ	*0.81*	*0.06*	*0.33*	*0.21*	*0.04*	*0.10*	*0.27*	*0.27*	*0.08*	*0.08*	*0.13*	*1.13*	
TLM-027-1 (UA81-243-0491)	AT-3181	Devil	mean	74.05	0.23	14.14	1.62	0.08	0.47	2.41	4.09	2.54	0.35	0.06	97.76	24
			1 δ	*0.44*	*0.04*	*0.20*	*0.11*	*0.04*	*0.04*	*0.13*	*0.12*	*0.06*	*0.04*	*0.07*	*0.95*	
TLM-088-1 (UA81-248-0023)	AT-3194-P1	Devil	mean	73.58	0.25	14.44	1.69	0.09	0.52	2.50	4.16	2.40	0.36	0.06	97.11	14
			1 δ	*0.45*	*0.02*	*0.18*	*0.13*	*0.04*	*0.04*	*0.13*	*0.10*	*0.08*	*0.04*	*0.10*	*0.96*	
	AT-3194-P2		mean	77.09	0.27	12.65	1.44	0.06	0.36	2.14	3.81	1.98	0.18	0.05	97.34	3
			1 δ	*0.32*	*0.04*	*0.10*	*0.41*	*0.03*	*0.03*	*0.50*	*0.22*	*0.79*	*0.08*	*0.05*	*0.66*	
	AT-3194-P3		mean	70.12	0.55	14.82	2.78	0.14	0.73	2.66	5.28	2.63	0.18	0.15	99.05	2
			1 δ	*0.53*	*0.05*	*0.23*	*0.38*	*0.01*	*0.24*	*1.01*	*0.67*	*0.34*	*0.01*	*0.06*	*0.02*	
	AT-3194-P4			67.69	0.53	15.67	3.36	0.06	1.32	4.17	4.70	2.15	0.19	0.19	99.06	1
TLM-096-1 (UA81-250-0007)	AT-3205-P1	Devil	mean	73.25	0.27	14.46	1.77	0.07	0.54	2.55	4.14	2.60	0.36	0.04	97.00	15
			1 δ	*0.97*	*0.06*	*0.28*	*0.27*	*0.04*	*0.08*	*0.26*	*0.46*	*0.14*	*0.07*	*0.10*	*0.93*	
	AT-3205-P2		mean	69.27	0.57	15.13	2.99	0.11	0.92	3.41	4.67	2.61	0.21	0.14	98.24	4
			1 δ	*0.39*	*0.03*	*0.06*	*0.06*	*0.02*	*0.05*	*0.16*	*0.13*	*0.02*	*0.03*	*0.01*	*0.58*	
	AT-3205-P3			70.37	0.13	16.97	0.83	0.01	0.13	4.38	5.14	1.76	0.30	0.03	96.84	1
014-131	AT-3221-P1	Devil	mean	71.12	0.46	14.60	2.53	0.09	0.75	2.97	4.54	2.53	0.30	0.16	98.43	7
			1 δ	*1.06*	*0.12*	*0.31*	*0.46*	*0.03*	*0.18*	*0.27*	*0.23*	*0.08*	*0.14*	*0.12*	*1.63*	
	AT-3221-P2		mean	67.81	0.60	15.50	3.55	0.13	1.18	4.03	4.55	2.34	0.15	0.18	99.49	4
			1 δ	*0.44*	*0.03*	*0.06*	*0.12*	*0.05*	*0.06*	*0.07*	*0.23*	*0.06*	*0.01*	*0.07*	*0.49*	
	AT-3221-P3		mean	77.24	0.23	12.33	1.39	0.02	0.30	2.12	3.89	2.06	0.29	0.16	98.40	3
			1 δ	*0.75*	*0.06*	*0.22*	*0.28*	*0.05*	*0.12*	*0.50*	*0.28*	*0.68*	*0.13*	*0.16*	*1.46*	
	AT-3221-P4		mean	73.34	0.24	14.52	1.86	0.07	0.52	2.56	3.84	2.62	0.38	0.12	97.17	2
			1 δ	0.35	0.00	0.02	0.11	0.06	0.07	0.11	0.02	0.04	0.03	0.10	0.84	
TLM-00143 (UA82-083)	AT-3442	Devil	mean	73.26	0.26	14.40	1.79	0.07	0.54	2.60	4.08	2.62	0.38	0.05	98.59	23
			1 δ	*0.48*	*0.02*	*0.19*	*0.14*	*0.04*	*0.05*	*0.10*	*0.17*	*0.06*	*0.05*	*0.11*	*0.83*	
TLM-128 (UA82-068)	AT-3445-P1	Devil	mean	73.55	0.25	14.26	1.71	0.09	0.50	2.50	4.16	2.60	0.37	0.07	98.47	22
			1 δ	*0.68*	*0.05*	*0.27*	*0.18*	*0.05*	*0.05*	*0.15*	*0.19*	*0.12*	*0.09*	*0.05*	*0.90*	
	AT-3445-P2			69.66	0.43	14.21	2.84	0.12	1.80	3.95	4.35	2.35	0.37	-0.01	98.41	1

[a]State Historic Preservation Office Alaska Historic Resources Survey number, University of Alaska Museum of the North identification in parentheses; [b]Alaska Tephra Laboratory and Data Center identification number (AT #); [c]Unit refers to unofficially named tephras from the mSRV.

Reported compositions are weight percent averages of n points, normalized to 100 percent; total gives original sum, 1 σ is standard deviation, not standard deviation of the mean. Raw point data given in supplemental file. P-, population; raw, original raw total.

Table 4.3. Major-oxide glass compositions of archaeological Watana tephra, determined by electron probe microanalyzer at the University of Alaska Fairbanks Advanced Instrumentation Laboratory.

Sample Name[a]	AT-#[b]	Unit[c]		SiO_2	TiO_2	Al_2O_3	FeO_T	MnO	MgO	CaO	Na_2O	K_2O	Cl	P_2O_5	TOTAL$_{raw}$	n
TLM-027-5	AT-3185	Oxidized Watana	mean	73.81	0.24	14.27	1.68	0.09	0.50	2.43	4.09	2.56	0.35	0.04	97.90	20
(UA81-243-0491)			*1 δ*	*0.57*	*0.03*	*0.22*	*0.16*	*0.05*	*0.04*	*0.16*	*0.14*	*0.06*	*0.04*	*0.07*	*0.64*	
TLM-027-6	AT-3186	Oxidized Watana	mean	73.45	0.24	14.52	1.69	0.07	0.50	2.54	4.10	2.52	0.36	0.06	97.20	21
(UA81-243-0491)			*1 δ*	*0.75*	*0.03*	*0.45*	*0.13*	*0.04*	*0.04*	*0.23*	*0.22*	*0.13*	*0.03*	*0.09*	*0.90*	
TLM-128	AT-3444-P1	Unoxidized Watana	mean	73.60	0.25	14.28	1.72	0.09	0.51	2.52	4.07	2.57	0.38	0.09	98.70	22
(UA82-068)			*1 δ*	*0.39*	*0.02*	*0.20*	*0.12*	*0.03*	*0.04*	*0.09*	*0.17*	*0.06*	*0.04*	*0.09*	*0.47*	
	AT-3444-P2			66.78	0.20	18.33	1.75	0.05	0.75	5.56	4.62	1.65	0.19	0.15	100.00	1
TLM-040, Unit 4-B	AT-3448	Unoxidized Watana	mean	73.53	0.25	14.39	1.50	0.06	0.53	2.58	4.14	2.64	0.38	0.06	97.38	21
			1 δ	*0.77*	*0.04*	*0.16*	*0.59*	*0.05*	*0.06*	*0.12*	*0.18*	*0.07*	*0.05*	*0.11*	*0.91*	
TLM-027-2	AT-3182	Watana	mean	73.51	0.25	14.42	1.74	0.08	0.51	2.54	4.00	2.56	0.36	0.10	97.93	24
(UA81-243-0491)			*1 δ*	*0.46*	*0.03*	*0.15*	*0.11*	*0.03*	*0.03*	*0.10*	*0.38*	*0.06*	*0.03*	*0.08*	*1.05*	
TLM-088-2	AT-3195-P1	Watana	mean	73.15	0.27	14.72	1.91	0.08	0.57	2.67	3.84	2.41	0.39	0.06	97.24	17
(UA81-248-0023)			*1 δ*	*0.54*	*0.04*	*0.20*	*0.19*	*0.04*	*0.05*	*0.18*	*0.48*	*0.13*	*0.04*	*0.11*	*0.84*	
	AT-3195-P2		mean	76.19	0.31	12.75	2.02	0.04	0.40	2.58	4.03	1.53	0.21	-0.03	98.24	3
			1 δ	*1.04*	*0.10*	*0.21*	*0.55*	*0.01*	*0.03*	*0.24*	*0.08*	*0.03*	*0.01*	*0.02*	*0.19*	
	AT-3195-P3			64.56	0.85	14.23	4.73	0.13	3.94	5.41	3.98	1.79	0.33	0.08	96.60	1
TLM-096-2	AT-3206-P1	Watana	mean	73.17	0.26	14.44	1.79	0.08	0.55	2.59	4.10	2.61	0.38	0.09	97.23	19
(UA81-250-0007)			*1 δ*	*0.63*	*0.04*	*0.22*	*0.15*	*0.04*	*0.08*	*0.15*	*0.32*	*0.09*	*0.05*	*0.09*	*1.27*	
	AT-3206-P2			64.72	0.54	16.21	4.03	0.03	2.25	5.72	4.17	1.88	0.25	0.24	98.12	1
011-266	AT-3219-P1	Watana	mean	72.84	0.27	14.55	1.83	0.09	0.58	2.73	4.10	2.60	0.40	0.08	97.29	21
			1 δ	*0.93*	*0.04*	*0.35*	*0.24*	*0.03*	*0.12*	*0.34*	*0.13*	*0.09*	*0.05*	*0.10*	*1.17*	
	AT-3219-P2			67.27	0.45	15.22	3.70	0.13	2.18	4.93	3.76	2.27	0.34	-0.19	97.55	1
014-163	AT-3220	Watana	mean	72.91	0.27	14.53	1.87	0.08	0.56	2.68	4.10	2.60	0.39	0.06	97.71	21
			1 δ	*0.55*	*0.03*	*0.19*	*0.14*	*0.04*	*0.11*	*0.16*	*0.37*	*0.05*	*0.04*	*0.06*	*0.91*	
TLM-00130	AT-3440	Watana	mean	73.26	0.27	14.46	1.66	0.07	0.56	2.63	4.10	2.60	0.38	0.08	98.27	22
(UA82-070)			*1 δ*	*1.08*	*0.06*	*0.23*	*0.49*	*0.04*	*0.12*	*0.26*	*0.22*	*0.13*	*0.06*	*0.05*	*1.29*	
TLM-00130	AT-3441-P1	Watana	mean	73.42	0.24	14.34	1.77	0.07	0.52	2.52	4.13	2.61	0.37	0.06	98.18	17
(UA82-070)			*1 δ*	*0.46*	*0.04*	*0.19*	*0.30*	*0.04*	*0.04*	*0.14*	*0.13*	*0.08*	*0.03*	*0.10*	*0.75*	
	AT-3441-P2		mean	69.53	0.55	14.99	3.02	0.10	0.92	3.36	4.70	2.52	0.18	0.15	98.89	4
			1 δ	*0.29*	*0.03*	*0.11*	*0.14*	*0.03*	*0.05*	*0.11*	*0.14*	*0.07*	*0.01*	*0.11*	*2.06*	

[a]State Historic Preservation Office Alaska Historic Resources Survey number, University of Alaska Museum of the North identification in parentheses; [b]Alaska Tephra Laboratory and Data Center identification number (AT #); [c]Unit refers to unofficially named tephras from the mSRV.
Reported compositions are weight percent averages of n points, normalized to 100 percent; total gives original sum, 1 σ is standard deviation, not standard deviation of the mean. Raw point data given in supplemental file. P-, population; raw, original raw total.

volcanic glass in addition to the primary population, 64 and 76 weight percent SiO_2. Sample AT-3206 contains a single point that differs from the primary population of volcanic glass, with 64 weight percent SiO_2. Lastly, AT-3441 contains a single minor sub-population with an average of 69 weight percent SiO_2.

Three other Oshetna tephra samples (AT-3183, AT-3193, and AT-3196) were analyzed in addition to the reference Oshetna tephra sample (AT-3188). Average glass compositions are shown in Table 4.4. Each sample contains at least four populations of volcanic glass and one sample contains five populations of volcanic glass (AT-3183). Primary populations differ in composition. General similarities, however, are apparent: each sample contains populations of glass with 67–68, 72–74, and 76–78 weight percent SiO_2. In addition, all of the Oshetna tephra samples, excepting the reference Oshetna tephra sample from site TLM-027, contain sub-populations of volcanic glass with averages of 63–64 weight percent SiO_2 and all of the Oshetna tephra samples but AT-3196 contain sub-populations of volcanic glass with averages of 70–71 weight percent SiO_2.

4.1.1.3 All other archaeological unknown tephra samples

Many archaeological tephra samples had provenience information as to the location the sample was taken from at an archaeological site—with specific information on the excavation unit, wall, and depth that was sampled—but lack information specifying which tephra unit was sampled. In some instances, this could be because all mSRV tephra were not present at the site thus making relative identifications impossible. For brevity, glass compositions for unknown tephra are not presented in this section; however, they are included in the supplementary file (Mulliken_2016_thesis_supplemental, Table S3 and S4).

4.1.1.4 Hayes Volcano reference tephra

Figure 4.2 plots total alkalis versus silica of Hayes River Outcrop tephra analyses from this study. Average glass compositions of proximal Hayes Volcano reference tephra from the Hayes River Outcrop (site 11HYKLW001 of Wallace et al. 2014; their Figure 5, my Figure 2.6) are shown in Table 4.5. Appendix D presents a comparison of Hayes River Outcrop tephra data of Wallace et al. (2014) with Hayes River Outcrop tephra data of this study (with similarity coefficients calculated between of the same tephras and mSRV tephras). Analysis of the

Table 4.4. Major-oxide glass compositions of archaeological Oshetna tephra, determined by electron probe microanalyzer at the University of Alaska Fairbanks Advanced Instrumentation Laboratory.

Sample Name[a]	AT-#[b]	Unit[c]		SiO_2	TiO_2	Al_2O_3	FeO_T	MnO	MgO	CaO	Na_2O	K_2O	Cl	P_2O_5	$TOTAL_{raw}$	n
TLM-027-8 (UA81-243-0491)	AT-3188-P1	Oshetna	mean	74.11	0.46	13.00	2.17	0.07	0.41	2.14	4.18	3.05	0.43	0.03	97.38	11
			1 δ	*0.28*	*0.04*	*0.24*	*0.10*	*0.05*	*0.09*	*0.30*	*0.60*	*0.92*	*0.22*	*0.11*	*1.36*	
	AT-3188-P2		mean	68.11	0.67	15.10	3.82	0.13	1.05	3.68	4.58	2.42	0.22	0.24	98.53	9
			1 δ	*0.54*	*0.27*	*0.55*	*0.52*	*0.06*	*0.12*	*0.37*	*0.21*	*0.46*	*0.03*	*0.16*	*1.23*	
	AT-3188-P3		mean	71.08	0.62	14.00	3.16	0.11	0.82	3.26	4.51	2.09	0.25	0.14	98.91	7
			1 δ	*0.65*	*0.20*	*0.68*	*0.56*	*0.06*	*0.10*	*0.31*	*0.12*	*0.24*	*0.03*	*0.07*	*0.30*	
	AT-3188-P4		mean	78.22	0.29	11.95	1.32	0.01	0.21	1.48	4.24	2.14	0.14	0.02	95.87	5
			1 δ	*0.82*	*0.06*	*0.47*	*0.12*	*0.02*	*0.11*	*0.59*	*0.70*	*1.08*	*0.06*	*0.08*	*0.57*	
TLM-027-3 (UA81-243-0491)	AT-3183-P1	Oshetna	mean	76.68	0.28	12.59	1.66	0.09	0.39	2.49	4.00	1.63	0.22	0.00	99.04	9
			1 δ	*0.22*	*0.03*	*0.09*	*0.09*	*0.03*	*0.02*	*0.04*	*0.18*	*0.11*	*0.02*	*0.07*	*0.70*	
	AT-3183-P2		mean	63.68	0.98	15.27	5.45	0.13	2.05	5.62	4.69	1.61	0.18	0.37	98.82	3
			1 δ	*0.50*	*0.01*	*0.11*	*0.16*	*0.01*	*0.13*	*0.21*	*0.12*	*0.07*	*0.02*	*0.10*	*0.19*	
	AT-3183-P3		mean	67.36	0.68	15.12	3.84	0.12	1.30	4.29	4.72	2.14	0.19	0.27	99.07	3
			1 δ	*1.02*	*0.18*	*0.58*	*0.98*	*0.04*	*0.21*	*0.37*	*0.09*	*0.28*	*0.03*	*0.04*	*0.25*	
	AT-3183-P4		mean	72.93	0.38	14.26	2.15	0.13	0.49	2.53	4.50	2.58	0.23	-0.16	98.65	2
			1 δ	*0.01*	*0.01*	*0.09*	*0.04*	*0.04*	*0.00*	*0.15*	*0.33*	*0.10*	*0.03*	*0.46*	*0.59*	
	AT-3183-P5			70.38	0.54	15.01	2.85	0.09	0.76	3.21	4.42	2.48	0.14	0.14	99.63	1
TLM-055-3 (UA81-246-0013)	AT-3193-P1	Oshetna	mean	68.30	0.58	15.71	3.27	0.11	1.09	3.92	4.58	2.17	0.19	0.10	97.79	13
			1 δ	*0.55*	*0.06*	*0.51*	*0.45*	*0.04*	*0.16*	*0.28*	*0.16*	*0.11*	*0.04*	*0.07*	*1.31*	
	AT-3193-P2		mean	64.69	0.98	14.79	5.69	0.12	1.80	5.26	4.60	1.64	0.21	0.25	99.21	5
			1 δ	*1.19*	*0.06*	*0.56*	*0.20*	*0.06*	*0.21*	*0.59*	*0.23*	*0.11*	*0.03*	*0.07*	*0.56*	
	AT-3193-P3		mean	74.32	0.34	13.60	1.88	0.07	0.41	2.06	4.52	2.67	0.19	-0.03	98.82	3
			1 δ	*0.84*	*0.06*	*0.27*	*0.28*	*0.01*	*0.03*	*0.12*	*0.21*	*0.14*	*0.02*	*0.16*	*1.63*	
	AT-3193-P4			76.89	0.27	12.61	1.48	0.02	0.38	2.41	4.17	1.56	0.23	0.03	97.94	1
TLM-088-3 (UA81-248-0023)	AT-3196-P1	Oshetna	mean	63.98	0.94	15.34	5.60	0.11	2.03	5.61	4.50	1.52	0.18	0.22	98.74	9
			1 δ	*1.21*	*0.04*	*0.19*	*0.46*	*0.03*	*0.30*	*0.49*	*0.26*	*0.11*	*0.03*	*0.14*	*0.43*	
	AT-3196-P2		mean	76.32	0.33	12.80	1.67	0.05	0.38	2.16	4.18	1.90	0.21	0.05	97.43	7
			1 δ	*0.87*	*0.06*	*0.56*	*0.11*	*0.03*	*0.04*	*0.32*	*0.19*	*0.50*	*0.02*	*0.06*	*1.20*	
	AT-3196-P3		mean	73.53	0.66	12.64	3.09	0.07	0.70	2.46	4.49	2.10	0.19	0.09	97.93	5
			1 δ	*1.27*	*0.08*	*0.46*	*0.34*	*0.05*	*0.15*	*0.35*	*0.17*	*0.15*	*0.06*	*0.06*	*1.61*	
	AT-3196-P4			68.64	0.44	17.06	1.93	0.07	0.40	5.27	4.51	1.41	0.15	0.14	98.47	1

[a]State Historic Preservation Office Alaska Historic Resources Survey number, University of Alaska Museum of the North identification in parentheses; [b]Alaska Tephra Laboratory and Data Center identification number (AT #); [c]Unit refers to unofficially named tephras from the mSRV.
Reported compositions are weight percent averages of n points, normalized to 100 percent; total gives original sum, 1 σ is standard deviation, not standard deviation of the mean. Raw point data given in supplemental file. P-, population; raw, original raw total.

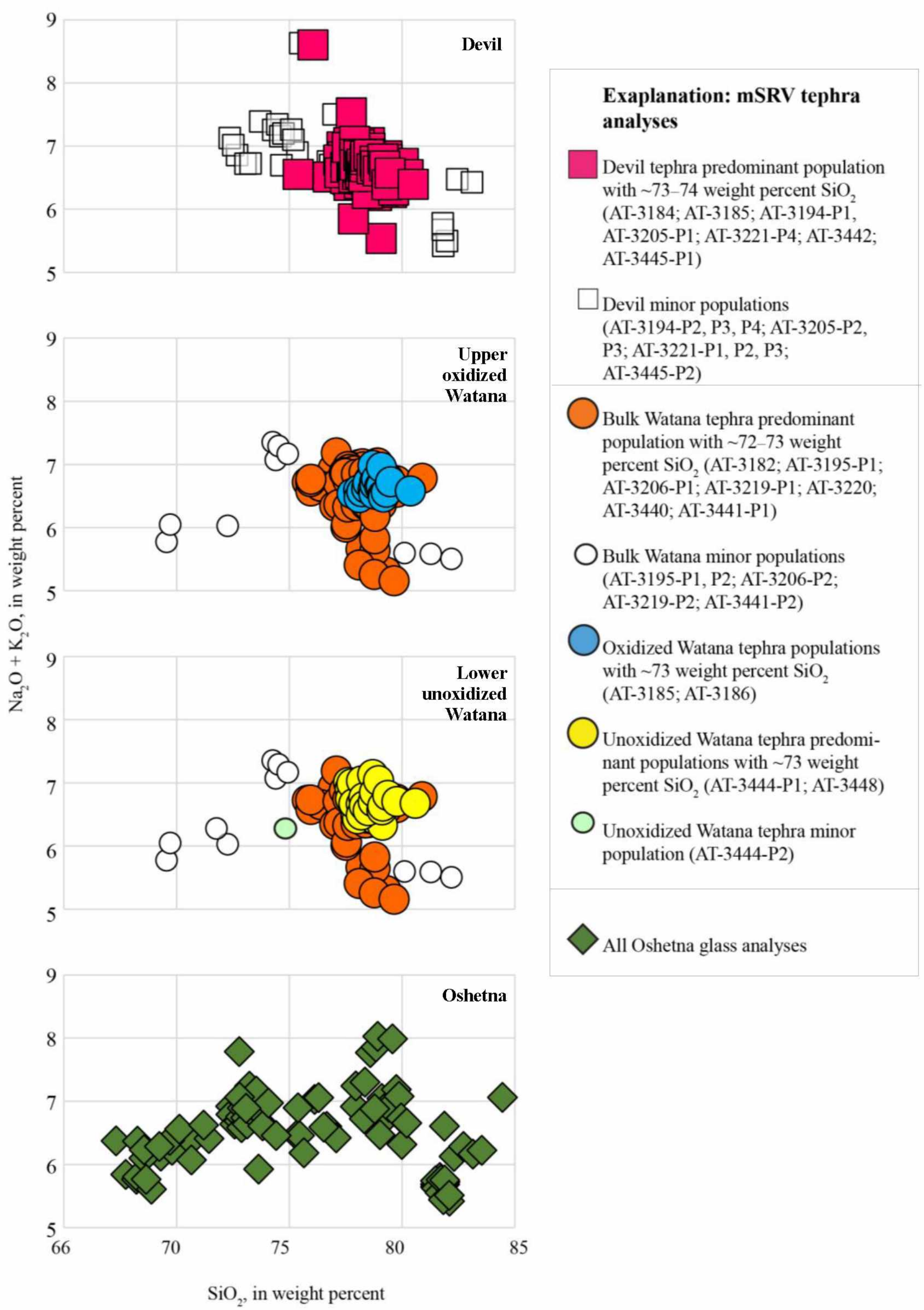


Figure 4.1. Composition of mSRV tephra, total alkali versus SiO_2.

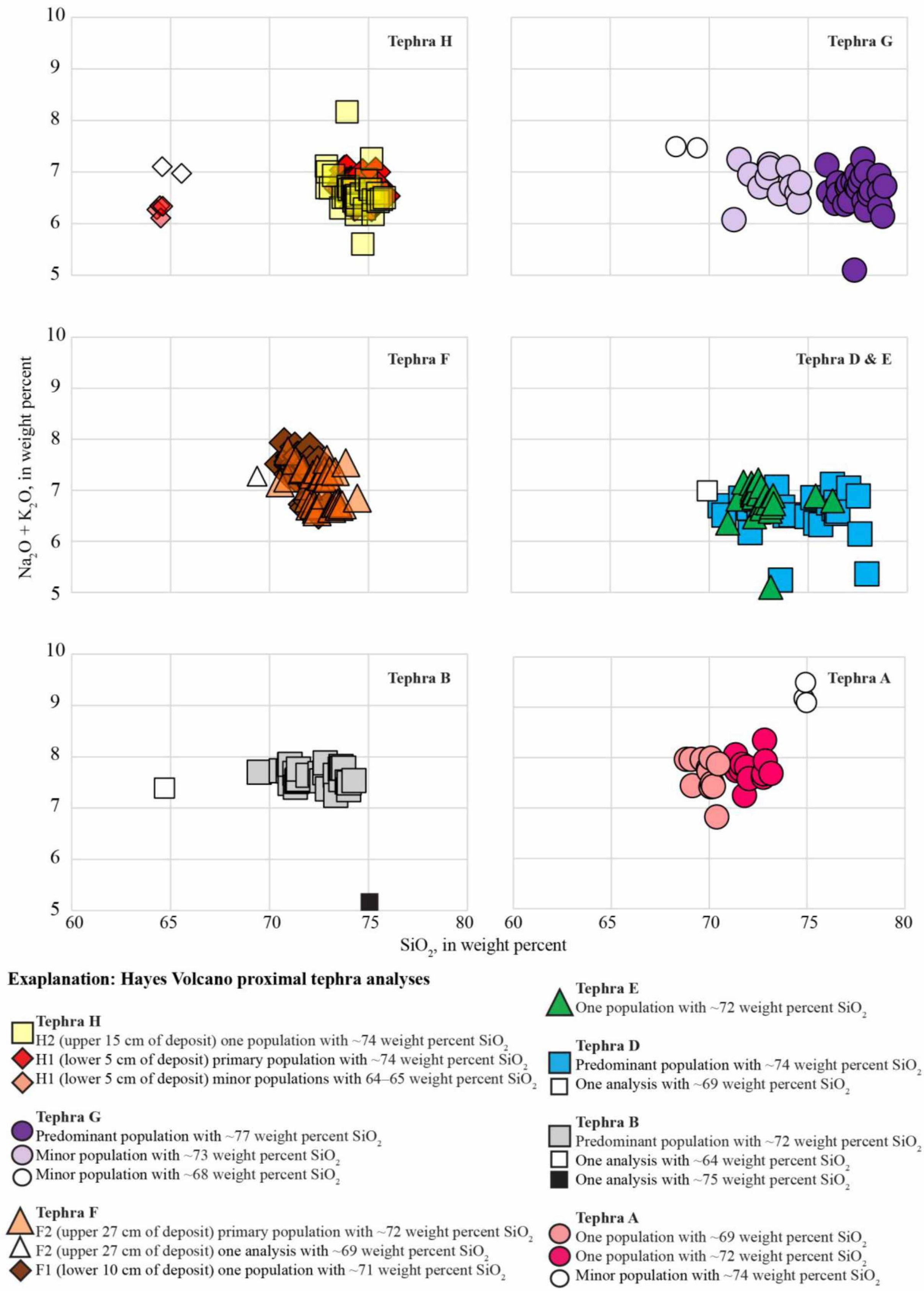


Figure 4.2. Composition of Hayes Volcano proximal tephra (of Wallace et al. 2014), total alkali versus SiO_2.

Table 4.5. Major-oxide glass compositions of proximal Hayes Volcano tephra (reanalyzed from Wallace et al. 2014), determined by electron probe microanalyzer at the University of Alaska Fairbanks Advanced Instrumentation Laboratory.

Sample Name[a]	AT-#[b]	Unit[c]		SiO_2	TiO_2	Al_2O_3	FeO_T	MnO	MgO	CaO	Na_2O	K_2O	Cl	P_2O_5	$TOTAL_{raw}$	n
11HYKLW001-11	AT-2564	H2	mean	74.48	0.24	13.50	1.83	0.08	0.44	2.39	3.87	2.64	0.55	0.06	98.69	35
			1 δ	*0.90*	*0.04*	*0.43*	*0.16*	*0.04*	*0.05*	*0.25*	*0.51*	*0.24*	*0.07*	*0.07*	*1.23*	
11HYKLW001-10	AT-2563-P1	H1	mean	74.45	0.25	13.37	1.83	0.06	0.43	2.42	4.17	2.45	0.57	0.08	98.88	29
			1 δ	*0.72*	*0.03*	*0.24*	*0.25*	*0.03*	*0.05*	*0.19*	*0.48*	*0.09*	*0.08*	*0.11*	*1.33*	
	AT-2563-P2		mean	64.47	0.56	16.24	4.30	0.15	1.97	5.57	4.52	1.75	0.31	0.21	98.76	4
			1 δ	*0.12*	*0.05*	*0.31*	*0.13*	*0.10*	*0.05*	*0.07*	*0.11*	*0.03*	*0.02*	*0.18*	*1.62*	
	AT-2563-P3		mean	65.08	0.21	19.28	1.70	0.04	0.65	5.74	5.63	1.41	0.24	0.07	100.57	2
			1 δ	*0.69*	*0.01*	*0.88*	*0.40*	*0.01*	*0.04*	*0.24*	*0.28*	*0.19*	*0.00*	*0.07*	*0.12*	
11HYKLW001-9	AT-2562-P1	G	mean	77.56	0.27	11.73	1.45	0.06	0.27	1.48	3.73	2.83	0.59	0.12	96.42	28
			1 δ	*0.85*	*0.03*	*0.55*	*0.16*	*0.06*	*0.08*	*0.30*	*0.46*	*0.14*	*0.07*	*0.17*	*1.25*	
	AT-2562-P2		mean	73.19	0.25	14.28	1.52	0.07	0.53	3.10	4.40	2.23	0.49	0.02	97.32	14
			1 δ	*1.09*	*0.08*	*1.14*	*0.74*	*0.06*	*0.83*	*0.47*	*0.70*	*0.16*	*0.13*	*0.06*	*1.14*	
	AT-2562-P3		mean	68.86	0.15	17.60	0.94	0.03	0.14	4.47	5.75	1.73	0.25	0.11	97.90	2
			1 δ	*0.76*	*0.04*	*0.50*	*0.07*	*0.01*	*0.01*	*0.12*	*0.14*	*0.12*	*0.05*	*0.03*	*0.41*	
11HYKLW001-8	AT-2561-P1	F2	mean	72.59	0.27	14.35	1.98	0.07	0.54	2.64	4.50	2.53	0.50	0.09	98.49	31
			1 δ	*0.96*	*0.04*	*0.34*	*0.27*	*0.04*	*0.06*	*0.24*	*0.57*	*0.06*	*0.06*	*0.11*	*1.26*	
	AT-2561-P2			69.37	0.23	16.25	1.73	0.14	0.43	4.12	5.20	2.08	0.40	0.11	100.70	1
11HYKLW001-7	AT-2560	F1	mean	71.58	0.30	14.50	2.15	0.09	0.62	2.83	4.86	2.51	0.55	0.10	98.70	33
			1 δ	*0.56*	*0.03*	*0.20*	*0.15*	*0.04*	*0.08*	*0.17*	*0.37*	*0.08*	*0.05*	*0.08*	*1.17*	
11HYKLW001-13	AT-2565	E	mean	72.69	0.29	14.31	2.04	0.09	0.55	2.65	4.22	2.57	0.58	0.09	98.23	29
			1 δ	*1.01*	*0.05*	*0.45*	*0.32*	*0.06*	*0.08*	*0.30*	*0.37*	*0.10*	*0.09*	*0.11*	*1.15*	
11HYKLW001-15	AT-2567-P1	D	mean	74.50	0.24	13.99	1.54	0.08	0.40	2.43	4.12	2.30	0.37	0.08	98.46	32
			1 δ	*2.09*	*0.07*	*0.93*	*0.48*	*0.05*	*0.18*	*0.80*	*0.69*	*0.42*	*0.11*	*0.11*	*1.11*	
	AT-2567-P2			69.91	0.15	17.43	0.79	0.07	0.16	4.22	5.15	1.83	0.28	0.05	95.79	1
11HYKLW001-6	AT-2559-P1	B	mean	72.49	0.27	14.12	1.86	0.09	0.53	2.60	5.38	2.15	0.42	0.15	99.28	30
			1 δ	*1.39*	*0.04*	*0.42*	*0.32*	*0.04*	*0.09*	*0.36*	*0.56*	*0.12*	*0.07*	*0.18*	*1.09*	
	AT-2559-P2			64.70	0.55	15.93	4.25	0.05	1.80	4.83	5.63	1.76	0.48	0.11	95.81	1
	AT-2559-P3			75.38	0.27	14.23	1.85	0.07	0.51	2.36	2.64	2.15	0.36	0.23	97.93	1
11HYKLW001-5	AT-2558-P1	A	mean	69.84	0.37	14.95	2.51	0.09	0.77	3.30	5.71	1.95	0.49	0.09	99.71	12
			1 δ	*0.54*	*0.03*	*0.27*	*0.13*	*0.05*	*0.06*	*0.14*	*0.35*	*0.05*	*0.06*	*0.10*	*0.95*	
	AT-2558-P2		mean	72.19	0.28	14.16	1.90	0.10	0.56	2.63	5.43	2.35	0.45	0.02	98.81	12
			1 δ	*0.65*	*0.03*	*0.31*	*0.19*	*0.04*	*0.06*	*0.16*	*0.27*	*0.17*	*0.10*	*0.13*	*1.35*	
	AT-2558-P3		mean	74.93	0.02	14.14	0.51	0.16	0.10	0.68	5.28	3.97	0.07	0.14	95.53	3
			1 δ	*0.06*	*0.01*	*0.09*	*0.05*	*0.01*	*0.01*	*0.06*	*0.15*	*0.08*	*0.01*	*0.13*	*0.04*	

[a]USGS AVO sample names; [b]Alaska Tephra Laboratory and Data Center identification number (AT #); [c]Unit refers to unofficially named tephras from the Hayes River Outcrop (of Wallace et al. 2014).

Reported compositions are weight percent averages of n points, normalized to 100 percent; total gives original sum, 1 σ is standard deviation, not standard deviation of the mean. Raw point data given in supplemental file. P-, population; raw, original raw total.

uppermost tephra, which was sub-sampled, demonstrates that the upper 15 cm of the deposit (H2, AT-2564) has one population of glass with an average of 74 weight percent SiO_2. The lower 5 cm of the deposit (H1, AT-2563) contains three populations of volcanic glass: a primary population with an average 74 weight percent SiO_2, and two minor sub-populations with 64 and 65 weight percent SiO_2 (differences in other oxide weight percents suggest the two are independent). Three populations of glass are identified in tephra G (AT-2562), which is located stratigraphically below tephra H—68, 73, and 77 weight percent SiO_2.

Tephra F directly below tephra G, was also sub-sampled. The upper 27 cm (F2, AT-2561) is primarily composed of one population of glass with 72 weight percent SiO_2; however, one point of analysis with 69 weight percent SiO_2 may constitute a second population. The lower 10 cm of tephra F (F1, AT-2560) has one population of 71 weight percent SiO_2. Tephra E, directly below tephra F, also contains a single population of glass with an average of 72 weight percent SiO_2. Analysis of tephra D (AT-2567) appears to be compositionally heterogeneous, with SiO_2 ranging from 69–77 weight percent and no clear indication of discrete populations, except in the case of a single point with 69 weight percent SiO_2. Therefore, these data are given as a single population with an average of 74 weight percent SiO_2 and a high higher standard deviation indicative of the sample being heterogeneous. Tephra B (AT-2559), located below tephra D, also proved difficult to separate into individual populations of volcanic glass, with individual points ranging from 64–75 weight percent SiO_2 and little indication of distinct population separation. Therefore, tephra B is characterized as having a primary population of glass with an average of 72 weight percent SiO_2; two individual points with 64 and 75 weight percent SiO_2 are also noted. Lastly, tephra A, the oldest at the Hayes River Outcrop (older than the Hayes tephra set H) is comprised of three populations of volcanic glass, with averages of 69, 72, and 74 weight percent SiO_2.

4.1.2 Similarity coefficient

The results obtained for the SIMAN similarity coefficient calculations between tephra are presented in this section. Similarity coefficients are calculated between reference mSRV tephra, proximal Hayes Volcano reference tephra (from Hayes River Outcrop, site 11HYKLW001 of Wallace et al. 2014) and all samples of the mSRV Devil, Watana, and Oshetna tephras. Calculation of similarity coefficients was done in an effort to establish geochemical correlations among these datasets, including within-deposit variability. Similarity coefficients (SC) $\geq$ 0.90 are presented, as they are interpreted as demonstrating correlations of sufficient magnitude between tephra layers indicative of origination from the same volcano (following Begét et al. 1991). SC $\geq$ 0.95 are emphasized in discussion, as these values are interpreted as being indicative of the same volcanic event or members of the same set (following Begét et al. 1991)

4.1.2.1 Correlating mSRV reference tephra with proximal Hayes Volcano reference tephra

Results of the similarity coefficient calculations between the mSRV reference tephra from sites TLM-027 and TLM-128 and proximal Hayes Volcano reference tephra are shown in Table 4.6. The mSRV Devil reference tephra sample (AT-3184) has similarity coefficients greater than 0.95 for two Hayes Volcano reference tephra: 0.97 with tephra F2 (AT-2560-P1) and 0.97 with tephra E (AT-2565). The uppermost oxidized mSRV Watana reference tephra sample (AT-3185) has three similarity coefficients $\geq$ 0.95 with Hayes Volcano reference tephra: 0.95 with tephra H2 (AT-2564), 0.95 with tephra H1 (AT-2563-P1), and 0.96 with tephra D (AT-2567-P1). The mSRV oxidized Watana reference tephra sample (AT-3186) does not have similarity coefficients $\geq$ 0.95 with any Hayes Volcano reference tephra. The unoxidized

Table 4.6. Similarity coefficients between Hayes Volcano reference tephra (reanalyzed from Wallace et al. 2014) and mSRV archaeological reference tephra from sites TLM-027 and TLM-128.

		Archaeological reference tephra from sites TLM-027 and TLM-128							
	Unit[a] AT-#[b]	AT-3184 Devil	AT-3185 Uppermost Oxidized Watana	AT-3186 Oxidized Watana	AT-3444-P1 Unoxidized Watana	AT-3188-P1 Oshetna	AT-3188-P2 Oshetna	AT-3188-P3 Oshetna	AT-3188-P4 Oshetna
Hayes Volcano reference tephra from site 11HYKLW001	AT-2564-H2	0.94	**0.96**	**0.95**	**0.95**	-	-	-	-
	AT-2563-P1-H1	0.94	**0.95**	**0.95**	**0.95**	-	-	-	-
	AT-2563-P2 -H1	-	-	-	-	-	-	-	-
	AT-2563-P3-H1	-	-	-	-	-	-	-	-
	AT-2562-P1-G	-	-	-	-	-	-	-	0.93
	AT-2562-P2-G	0.93	0.92	0.93	0.93	-	-	-	-
	AT-2562-P3 -G	-	-	-	-	-	-	-	-
	AT-2561-P1-F2	**0.97**	0.94	0.94	**0.95**	-	-	-	-
	AT-2560-F1	0.92	-	-	-	-	-	-	-
	AT-2565-E	**0.97**	0.93	0.94	**0.95**	-	-	-	-
	AT-2567-P1-D	0.93	**0.96**	**0.95**	0.94	-	-	-	-
	AT-2559-P1-B	0.94	0.91	0.91	0.92	-	-	-	-
	AT-2558-P1-A	-	-	-	-	-	-	-	-
	AT-2558-P2-A	0.94	0.90	0.91	0.91	-	-	-	-
	AT-2558-P3-A	.	-	-	-	-	-	-	-

[a]Unit refers to unofficially named tephras from the mSRV OR Hayes Volcano proximal tephra as reported in Wallace et al. (2014); [b]Alaska Tephra Laboratory and Data Center identification number (AT #);-value <0.90 and therefore not reported.

Watana tephra (AT-3444-P1) has a similarity coefficient of 0.95 with Hayes Volcano reference tephra H1 (AT-2563). None of the glass populations in the mSRV Oshetna reference tephra (AT-3188) have a similarity coefficient ≥ 0.95 with Hayes Volcano reference tephra.

Similarity coefficients are also calculated between other mSRV archaeological tephra samples (from known informal mSRV tephra units) and Hayes Volcano reference tephra. Results of similarity coefficient calculation between archaeological Devil tephra and all Hayes Volcano reference tephra samples are shown in Table 4.7. Volcanic glass populations in the Devil tephra correlate (with similarity coefficients ≥ 0.95) to populations of volcanic glass in proximal Hayes Volcano tephra D, E, F2, H2, and H1 at the Hayes River Outcrop. Results of similarity coefficient calculations between all Watana tephra samples and Hayes Volcano reference tephra samples are shown in Table 4.8. Watana tephra samples have similarity coefficients ≥ 0.95 with proximal tephra D, E, F2, H2, and H1. Results of similarity coefficient calculations between all Oshetna tephra samples and Hayes Volcano reference tephra are show in Table 4.9; there are no correlation coefficients ≥ 0.95 with any proximal Hayes Volcano reference tephra from the Hayes River Outcrop, which is to be expected given the earlier timeframe of Oshetna tephra deposition.

Table 4.7. Similarity coefficients between Hayes Volcano reference tephra (reanalyzed from Wallace et al. 2014) and mSRV archaeological Devil tephra from sites TLM-027, TLM-088, TLM-096, HEA-189, TLM-143, and TLM-128.

		Archaeological Devil tephra geochemical populations												
	Unit[a] AT-#[b]	AT-3184	AT-3181	AT-3194-P1	AT-3194-P2	AT-3194-P3	AT-3205-P1	AT-3205-P2	AT-3221-P1	AT-3221-P2	AT-3221-P3	AT-3221-P4	AT-3442	AT-3445-P1
Hayes Volcano reference tephra from site 11HYKLW001	AT-2564-H2	0.94	**0.95**	0.93	-	-	0.93	-	-	-	-	**0.96**	0.94	**0.95**
	AT-2563-H1-P1	0.94	-	**0.95**	-	-	0.94	-	-	-	-	0.94	0.94	**0.95**
	AT-2563 -H1-P2	-	-	-	-	-	-	-	-	-	-	-	-	-
	AT-2563-H1-P3	-	-	-	-	-	-	-	-	-	-	-	-	-
	AT-2562-G-P1	-	-	-	-	-	-	-	-	-	-	-	-	-
	AT-2562-G-P2	0.93	0.92	0.94	-	-	0.92	-	-	-	-	0.91	0.92	0.93
	AT-2562-G-P3	-	-	-	-	-	-	-	-	-	-	-	-	-
	AT-2561-F2-P1	**0.97**	0.92	**0.95**	-	-	**0.97**	-	-	-	-	**0.95**	**0.97**	**0.95**
	AT-2560-F1	0.92	-	-	-	-	0.92	-	0.91	-		-	0.91	-
	AT-2565-E	**0.97**	0.92	0.94	-	-	**0.97**	-	-	-	-	0.94	**0.96**	0.94
	AT-2567-D-P1	0.93	**0.96**	**0.95**	0.93	-	0.93	-	-	-	0.91	0.92	0.92	0.94
	AT-2559-B-P1	0.94	-	0.93	-	-	0.93	-	-	-	-	0.92	0.93	0.92
	AT-2558-A-P1	-	-	-	-	-	-	-	-	-	-	-	-	-
	AT-2558-A-P2	0.94	-	0.92	-	-	0.93	-	-	-	-	0.91	0.93	0.91
	AT-2558-A-P3	-	-	-	-	-	-	-	-	-	-	-	-	-

[a]Unit refers to unofficially named tephras from the mSRV OR Hayes Volcano proximal tephra as reported in Wallace et al. (2014); [b]Alaska Tephra Laboratory and Data Center identification number (AT #);-value <0.90 and therefore not reported.

Table 4.8. Similarity coefficients between Hayes Volcano reference tephra (reanalyzed from Wallace et al. 2014) and mSRV archaeological Watana tephra from sites TLM-027, TLM-088, TLM-096, HEA-189, and TLM-130.

	Unit[a] AT-#[b]	AT-3185 Ox	AT-3186 Ox	AT-3444-P1 Unox	AT-3448 Unox	AT-3182	AT-3219 P1	AT-3219 P2	AT-3219 P3	AT-3195 P1	AT-3195 P2	AT-3206 P1	AT-3219 P1	AT-3220	AT-3440	AT-3441 P1	AT-3441-P2
		Archaeological Watana tephra geochemical populations															
Hayes Volcano reference tephra from site 11HYKLW001	AT-2564-H2	**0.96**	**0.95**	**0.95**	0.93	**0.95**	0.92	0.90	-	0.92	-	0.94	0.93	0.93	0.92	**0.95**	-
	AT-2563-H1-P1	**0.95**	**0.95**	**0.95**	0.93	**0.95**	0.92	0.91	-	0.92	-	**0.98**	0.93	0.93	0.93	**0.95**	-
	AT-2563 -H1-P2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	AT-2563-H1-P3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	AT-2562-G-P1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	AT-2562-G-P2	0.92	0.93	0.93	0.94	0.93	0.92	-	-	0.92	-	0.92	0.92	0.92	0.93	0.92	-
	AT-2562-G-P3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	AT-2561-F2-P1	0.94	0.94	**0.95**	**0.95**	**0.95**	**0.97**	-	-	**0.96**	-	**0.96**	**0.96**	**0.97**	**0.96**	**0.95**	-
	AT-2560-F1	-	-	-	-	-	0.94	-	-	0.92	-	0.91	0.93	0.93	0.92	-	-
	AT-2565-E	0.93	0.94	**0.95**	**0.95**	0.94	**0.98**	-	-	**0.96**	-	**0.96**	**0.97**	**0.97**	**0.97**	**0.95**	-
	AT-2567-D-P1	**0.96**	**0.95**	0.94	0.94	0.94	0.91	**0.93**	-	0.91	-	0.92	0.91	0.92	0.93	0.94	-
	AT-2559-B-P1	0.91	0.91	0.92	0.91	0.92	0.92	-	-	0.93	-	0.93	0.92	0.93	0.92	0.92	-
	AT-2558-A-P1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	AT-2558-A-P2	0.90	0.91	0.91	0.91	0.92	0.94	-	-	0.95	-	0.93	0.93	0.94	0.93	0.92	-
	AT-2558-A-P3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

[a]Unit refers to unofficially named tephras from the mSRV OR Hayes Volcano proximal tephra as reported in Wallace et al. (2014); [b]Alaska Tephra Laboratory and Data Center identification number (AT #);-value <0.90 and therefore not reported. Note that "Ox" and "Unox" denote whether sample came from the upper oxidized or lower unoxidized portion of the Watana tephra.

Table 4.9. Similarity coefficients between Hayes Volcano reference tephra (reanalyzed from Wallace et al. 2014) and mSRV archaeological Oshetna tephra from sites TLM-027, TLM-055, TLM-088.

	Unit[a] AT-#[b]	AT-3188-P1	AT-3188-P2	AT-3188-P3	AT-3188-P4	AT-3183 P1	AT-3183 P2	AT-3183 P3	AT-3183 P4	AT-3193 P1	AT-3193 P2	AT-3193 P3	AT-3196 P1	AT-3196 P2	AT-3196 P3
		Archaeological Oshetna tephra geochemical populations													
Hayes Volcano reference tephra from site 11HYKLW001	AT-2564-H2	-	-	-	-	-	-	-	-	-	-	0.92	-	-	-
	AT-2563-H1-P1	-	-	-	-	0.90	-	-	-	-	-	0.92	-	0.90	-
	AT-2563 -H1-P2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	AT-2563-H1-P3	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	AT-2562-G-P1	-	-	-	0.93	-	-	-	-	-	-	-	-	-	-
	AT-2562-G-P2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	AT-2562-G-P3	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	AT-2561-F2-P1	-	-	-	-	-	-	-	0.94	-	-	-	-	-	-
	AT-2560-F1	-	-	-	-	-	-	-	0.92	-	-	-	-	-	-
	AT-2565-E	-	-	-	-	-	-	-	0.94	-	-	-	-	-	-
	AT-2567-D-P1	-	-	-	-	0.91	-	-	-	-	-	-	-	0.91	-
	AT-2559-B-P1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	AT-2558-A-P1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	AT-2558-A-P2	-	-	-	-	-	-	-	0.9	-	-	-	-	-	-
	AT-2558-A-P3	-	-	-	-	-	-	-	-	-	-	-	-	-	-

[a]Unit refers to unofficially named tephras from the mSRV OR Hayes Volcano proximal tephra as reported in Wallace et al. (2014); [b]Alaska Tephra Laboratory and Data Center identification number (AT #);-value <0.90 and therefore not reported.

4.1.2.2 Similarity coefficient between archaeological tephra samples for geochemical groups

The similarity correlation matrix for all Devil tephra samples are listed in Appendix E, along with all matrices for correlation between samples of the same tephras. Following Brochardt's (1974) protocols for group selection, analyses of those two samples with the highest similarity coefficient value were combined and re-averaged, after which similarity coefficients were recalculated in order to determine if other analyses of Devil tephra samples could be identified. Two geochemical groups were established as being present in the Devil tephra, one with an average of 73 weight percent SiO_2 (the average of seven samples of the Devil tephra primary composition) and another with an average of 77 weight percent SiO_2 (the average of two secondary minor populations in two samples of the Devil tephra). Results are shown in Table 4.10. Note that AT-3194-P3, AT-3205-P2, and AT-3221-P1 and P2 are not included in any Devil groups because similarity coefficients calculated between them other Devil samples are less than 0.95.

Distinguishing the Watana tephra into geochemical groups is complicated by stratigraphic distinctions between the upper oxidized and lower unoxidized portions of this tephra and by the lack of tephra samples taken from these stratigraphically distinct locations. Because only two samples each of the upper Oxidized Watana (AT-3185 and AT-3186) and lower unoxidized Watana (AT-3444 and AT-3448) were available, analyses of these samples are combined into stratigraphic Watana Group 1 and Watana Group 2; similarity coefficients calculated between samples within each group are ≥ 0.95 (see Appendix C, Table 4.10).

However, following Brochardt's (1974) protocols for geochemical group identification, all samples of Watana tephra are also treated equally (because of the lack of identification as to where the samples were originating stratigraphically) and distinguished as Watana geochemical Group 3, which is representative of the entire unit. Twelve geochemical populations distinguished in Watana tephra samples, having similarity coefficients ≥ 0.95, are combined into one geochemical group. Results of geochemical groups distinguished as part of the Watana tephra are shown in Table 4.10. AT-3192-P1 and P3, AT-3195-P2 and AT-3441-P2 did not have similarity coefficients ≥ 0.95 calculated between other geochemical populations and therefore are not incorporated into a Watana geochemical group.

Table 4.10. Major-oxide glass compositions of geochemical groups in archaeological mSRV tephra, determined by combining EPMA analyses of the same unit with glass population averages that have SC ≥0.95, or SC ≥0.90 for the Oshetna tephra.

Unit[a]	Group[b]		SiO_2	TiO_2	Al_2O_3	FeO_T	MnO	MgO	CaO	Na_2O	K_2O	Cl	P_2O_5	$TOTAL_{raw}$	n
Devil	Group 1	mean	73.45	0.26	14.34	1.74	0.08	0.52	2.54	4.12	2.56	0.39	0.07	97.81	144
		1 δ	*0.73*	*0.05*	*0.28*	*0.19*	*0.04*	*0.07*	*0.20*	*0.24*	*0.11*	*0.08*	*0.10*	*1.11*	
	Group 2	mean	77.17	0.25	12.49	1.41	0.04	0.33	2.13	3.85	2.02	0.23	0.10	97.87	6
		1 δ	*0.52*	*0.05*	*0.23*	*0.32*	*0.04*	*0.08*	*0.44*	*0.23*	*0.66*	*0.11*	*0.12*	*1.17*	
Oxidized Watana	Group 1	mean	73.62	0.24	14.39	1.68	0.08	0.50	2.49	4.09	2.54	0.36	0.05	97.54	41
		1 δ	*0.68*	*0.03*	*0.38*	*0.15*	*0.04*	*0.04*	*0.21*	*0.18*	*0.10*	*0.04*	*0.08*	*0.85*	
Unoxidized Watana	Group 2	mean	73.56	0.25	14.33	1.61	0.07	0.52	2.55	4.10	2.60	0.38	0.08	98.06	43
		1 δ	*0.60*	*0.03*	*0.19*	*0.43*	*0.04*	*0.05*	*0.11*	*0.18*	*0.08*	*0.05*	*0.10*	*0.97*	
Bulk Watana	Group 3	mean	73.32	0.26	14.44	1.75	0.08	0.53	2.59	4.07	2.57	0.38	0.07	97.76	239
		1 δ	*0.73*	*0.05*	*0.28*	*0.32*	*0.04*	*0.08*	*0.21*	*0.27*	*0.10*	*0.05*	*0.09*	*1.09*	
Oshetna	Group 1	mean	64.14	0.96	15.17	5.60	0.12	1.97	5.51	4.56	1.57	0.19	0.26	98.89	17
		1 δ	*1.12*	*0.04*	*0.40*	*0.35*	*0.04*	*0.26*	*0.49*	*0.23*	*0.11*	*0.03*	*0.12*	*0.47*	
	Group 2	mean	68.77	0.63	15.11	3.45	0.11	1.04	3.74	4.58	2.22	0.21	0.16	98.36	32
		1 δ	*1.40*	*0.18*	*0.85*	*0.60*	*0.05*	*0.19*	*0.44*	*0.17*	*0.31*	*0.04*	*0.12*	*1.16*	
	Group 3	mean	76.52	0.30	12.68	1.67	0.07	0.38	2.34	4.08	1.75	0.21	0.02	98.33	16
		1 δ	*0.60*	*0.05*	*0.37*	*0.09*	*0.04*	*0.03*	*0.26*	*0.20*	*0.35*	*0.02*	*0.07*	*1.23*	
	Group 4	mean	74.01	0.43	13.27	2.11	0.08	0.42	2.17	4.29	2.92	0.36	-0.01	97.81	16
		1 δ	*0.57*	*0.06*	*0.51*	*0.18*	*0.05*	*0.08*	*0.29*	*0.53*	*0.78*	*0.21*	*0.17*	*1.43*	

[a]Unit refers to unofficially named tephras from the mSRV; [b]Group designates the geochemical group that was defined using Brochardt's (1974) procedure.
Reported compositions are weight percent averages of n points, normalized to 100 percent; total gives original sum, 1 σ is standard deviation, not standard deviation of the mean. Raw point data given in supplemental file; P-, population; raw, original raw total.

In order to establish Oshetna tephra geochemical groups, a similarity coefficient of 0.90 (as opposed to 0.95) is used because the Oshetna does not have proximal reference samples to compare to, and the goal is rather to establish the geochemical groups that comprise the unit. Four geochemical groups are established within Oshetna tephra samples using Brochardt's (1974) procedure for establishing groups and a threshold similarity coefficient value of 0.90. Table 4.10 shows the compositions for each Oshetna geochemical group.

4.1.2.3 Similarity coefficient calculations between mSRV tephra unit geochemical groups and Hayes Volcano reference tephra

Table 4.11 shows similarity coefficients calculated between the geochemical groups defined in mSRV tephra units and geochemical data from Hayes Volcano reference tephras. Results are comparable to initial similarity coefficient calculations between mSRV reference tephra samples at TLM-027 and TLM-128 and Hayes Volcano reference samples (Section 4.1.2.1). The Devil geochemical Group 1 has similarity coefficients of 0.96 with Hayes Volcano reference tephra F2 (AT-2560-P1) and E (AT-2565), and a similarity coefficient of 0.95 with proximal tephra H1 (AT-2563-P1). Watana geochemical Group 1 (combined analyses of the

Table 4.11. Similarity coefficients between proximal Hayes Volcano reference tephra (reanalyzed from Wallace et al. 2014) and geochemical groups identified in mSRV archaeological tephra.

	Unit[a] AT-#[b]	Archaeological mSRV tephra geochemical groups: Devil Group 1	Devil Group 2	Watana Group 1 Ox	Watana Group 2 Unox	Watana Group 3
Hayes Volcano reference tephra from site 11HYKLW001	**AT-2564-H2**	0.94	-	**0.95**	0.94	0.94
	AT-2563-P1-H1	**0.95**	-	**0.95**	0.94	0.94
	AT-2563-P2 -H1	-	-	-	-	-
	AT-2563-P3-H1	-	-	-	-	-
	AT-2562-P1-G	-	-	-	-	-
	AT-2562-P2-G	0.93	-	0.93	0.93	0.93
	AT-2562-P3 -G	-	-	-	-	-
	AT-2561-P1-F2	**0.96**	-	0.94	**0.95**	**0.96**
	AT-2560-F1	0.91	-	-	-	0.91
	AT-2565-E	**0.96**	-	0.94	**0.95**	**0.96**
	AT-2567-P1-D	0.94	0.91	**0.95**	**0.95**	0.93
	AT-2559-P1-B	0.93	-	0.91	0.92	0.93
	AT-2558-P1-A	-	-	-	-	-
	AT-2558-P2-A	0.92	-	0.91	0.91	0.93
	AT-2558-P3-A	-		-	-	-

[a]Unit refers to unofficially named tephras from the mSRV OR Hayes Volcano proximal tephra as reported in Wallace et al. (2014); [b]Alaska Tephra Laboratory and Data Center identification number (AT #);-value <0.90 and therefore not reported. Note that "Ox" and "Unox" denote geochemical groups from combined analyses of samples from the upper oxidized or lower unoxidized portion of the Watana tephra in the mSRV.

upper oxidized Watana samples) has similarity coefficients of 0.95 with Hayes Volcano reference tephra H (H2, AT-2564 and H1, AT-2563-P1), and D (AT-2567-P1). Watana geochemical Group 2 (combined analyses of the two lower unoxidized Watana samples) has similarity coefficients of 0.95 with Hayes Volcano reference tephra F2 (AT-2560-P1), E (AT-2565), and D (AT-2567-P1). Watana geochemical Group 3, which considers all Watana tephra samples, has similarity coefficients of 0.96 with Hayes Volcano reference tephra F2 (AT-2560-P1), and E (AT-2565). None of the Oshetna geochemical groups have similarity coefficients greater than 0.90 with any Hayes Volcano reference tephra, which is expected.

4.1.3 Summary of tephra geochemical analyses and correlations

Results of geochemical analyses demonstrate that the Devil tephra has a relatively homogenous glass composition, with a primary glass population very similar to the Watana tephra, with 73 weight percent SiO_2; minor secondary populations may also be present in Devil tephra samples. Devil tephra samples have similarity coefficients of 0.95 or greater with five proximal Hayes Volcano reference tephra units: Hayes River Outcrop tephra H (both H2 and

H1), F2, E, and D (see Table 4.7). This suggests that the Devil tephra is a product of Hayes Volcano. Other than differences in particle size, color and texture (Wallace et al. 2014), there are not age constraints between these proximal units and thus it is not known if they were erupted at the same of different times.

Like the Devil tephra, the Watana tephra has a predominant glass composition of 73 weight percent SiO_2, although minor sub-populations of glass with differing weight percent SiO_2 may also be present in the Watana tephra. Similarity coefficients calculated between mSRV Watana reference tephra samples, which is separated into two units stratigraphically, and proximal Hayes Volcano reference tephra samples demonstrate that the Watana tephra is correlative with the Hayes tephra set H. Specifically, Watana tephra samples correlate, with similarity coefficients greater than 0.95, to Hayes River Outcrop tephras D, E, F2, H (both H1 and H2) (of Wallace et al. 2014). Of the twelve mSRV Watana tephra samples, nine have correlation coefficients greater than 0.95 with Hayes River Outcrop tephras F2 and E, whereas another five of the mSRV Watana tephra samples have correlation coefficients of 0.95 or greater with Hayes River Outcrop tephra H (both H1 and H2) (see Table 4.8). Archaeological tephra samples of the upper oxidized Watana tephra have the highest correlation coefficients with proximal Hayes River Outcrop tephra D and H (both H1 and H2), whereas archaeological tephra samples of the lower unoxidized Watana tephra have highest correlation coefficients with proximal Hayes River Outcrop units F2, E, and D (see Table 4.8).

Geochemical analyses indicate that the Oshetna tephra, previously reported as having two populations of volcanic glass (Dilley 1988; Child et al. 1990), actually has at least four populations of volcanic glass in the mSRV. Some populations of volcanic glass within the Oshetna tephra have similarity coefficients greater than 0.90 with proximal Hayes Volcano tephra samples (Table 4.9). None have similarity coefficients greater than 0.95, which is to be expected given the older age of Oshetna deposition relative to the timing of the Hayes tephra set exposed in the Hayes River Valley (Wallace et al. 2014). However, similarity coefficients greater than 0.90 calculated between Oshetna tephra samples and Hayes Volcano tephra suggest that the Oshetna may be a product of Hayes Volcano, despite the lack of biotite reported in the unit (Romick and Thorson 1983).

4.2 Results of chronometric evaluation

In this section, results of radiocarbon analyses are presented in three separate subsections: Subsection 4.2.1 presents the results of new radiocarbon analyses as part of this study; Subsection 4.2.2 presents the revised chronology for the mSRV; and, Subsection 4.2.3 presents the results of Bayesian calibration. For brevity, all dates in text are presented as ^{14}C yr B.P., but calibrated 2 σ ranges of these dates may be referenced in tables presented in this section.

4.2.1 New mSRV dates

Results of new radiocarbon analyses as part of this study are shown in Table 4.12; previous dates associated with the site and stratigraphic location are provided for comparison (see Table 3.3 for other sample information). Whereas the original date produced at site TLM-050 had a very large standard deviation, the date produced as part of this study, 330±20 ^{14}C yr B.P. (UGAMS-22178), has a smaller standard deviation, but nevertheless overlaps with the original date calibrated 2 σ range. At site TLM-216, the new date, 1790±20 ^{14}C yr B.P. (UGAMS-22181), does not overlap with calibrated 2 σ range of the original date produced in the 1980s, but suggests instead that the occupation at the site is younger.

At site TLM-217, cultural components bound the Devil tephra and both dates produced as part of this study have calibrated medians older than the dates produced from those cultural components in the 1980s. The cultural component above the Devil tephra is dated to 1840±20 ^{14}C yr B.P. (UGAMS-22182) as part of this project and does not overlap with calibrated 2 σ

Table 4.12. Results of University of Georgia Center for Applied Isotope Studies AMS analyses of mSRV radiocarbon samples submitted for this study.

Lab #[a]	Site[b]	^{14}C age, yr B.P.[c]	δ13C,‰[d]	Calibrated age (2 δ)[e]	Calibrated median[f]	Previous ^{14}C age, yr B.P.[g]	Previous date calibrated age (2 δ)[h]
UGAMS-22178	TLM-050	330±20	-24.9	310–462	385	280±245 (DIC-1904; UA80-	0–650
UGAMS-22181	TLM-216	1790±20	-24.7	1625–1812	1713	2070±60 (Beta-9899; UA84-59-	1887–2298
UGAMS-22182	TLM-217	1840±20	-24.9	1713–1825	1775	1670±50 (Beta-9898; UA84-58-	1416–1705
UGAMS-22183	TLM-217	1910±20	-25.25	1819–1896	1857	1770±190 (Beta-10791; UA84-	1304–2123
UGAMS-22179	TLM-143	5850±25	-24	6568–6740	6672	4440±120 (Beta-7698; UA82-	4729–5462
UGAMS-22180	TLM-134	7090±30	-24.2	7851–7971	7929	None	None

[a]University of Georgia Center for Applied Isotope Studies laboratory number; [b]State Historic Preservation Office Alaska Historic Resources Survey number for site identification; [c]Radiocarbon age in years before present; [d]δ13C,‰ is the measured ratio of stable carbon isotopes, reported in parts per thousand; [e and h]Calibrated age range to two standard deviations and [f]Calibrated median determined using the IntCal13 terrestrial calibration curve in the CALIB Program, version 7.1 (Reimer et al. 2013; Stuiver and Reimer 1993); [g]Previous ^{14}C age years B.P. gives any related dates obtained as part of the Susitna Hydroelectric Project (1979–1985), associated with the same sample re-dated as part of this project, or with the cultural component (original date lab numbers and UAMN identification for sample dated are given in parentheses).

range of the original date from that component. The cultural component below the Devil tephra is dated to 1910±20 ^{14}C yr B.P. (UGAMS-22183), which is within the calibrated 2 σ range of the original date from that component; however, the original date had a very wide standard deviation and therefore our understanding of this timing of this component is refined with this recent date.

The new date produced from the cultural component at site TLM-143, located between the Oshetna and Watana tephras, is older than the original date from the 1980s produced for that component and the two do not overlap within the calibrated 2 σ range. The new date suggests that the cultural occupation occurred 5850±25 ^{14}C yr B.P. (UGAMS-22179), which is roughly 1400 years older than the original radiocarbon age produced for that component (Beta-7698) (Dixon et al. 1985). Lastly, the stratigraphic date at site TLM-134 (which had no associated dates produced in the 1980s) provides a maximum date for the Oshetna tephra deposition, at 7090±30 ^{14}C yr B.P. (UGAMS-22180).

Although the dates produced as part of this study do not provide direct cross-checks of the dates produced during the 1980s, they do suggest there are some significant differences between the dates produced at different times. These differences could result from differences in the materials dated at different times, which has attempted to be controlled for in this study by dating materials from recovered from similar archaeological contexts at sites in the mSRV. The large standard deviations associated with the dates produced in the 1980s is problematic and the smaller standard deviations associated with the newly obtained dates allow the chronology of the area to be considered with greater precision.

4.2.2 Revised mSRV chronology

All raw radiocarbon dates from the mSRV considered appropriate (Table 3.4 and 4.12) are calibrated and sorted by stratigraphic position to show a general timeframe for stratigraphic development (Figure 4.3); nevertheless, stratigraphic incongruities are present. In particular, UGAMS-22226 (3170±20 ^{14}C yr B.P.) and Beta-401547 (2390±30 ^{14}C yr B.P.), which bracket the Watana tephra, are problematic in that these ages represent a reversal, as Beta-401547 is stratigraphically below UGAMS-22226, but has a younger age. Likewise, UGAMS-22182 (1840±20 ^{14}C yr B.P.), located stratigraphically above the Devil tephra, is older than UGAMS-22227 (1540±20 ^{14}C yr B.P.) and UGAMS-22181 (1790±20 ^{14}C yr B.P.), both of which are located stratigraphically below the Devil tephra. Evaluation of the dates is complicated

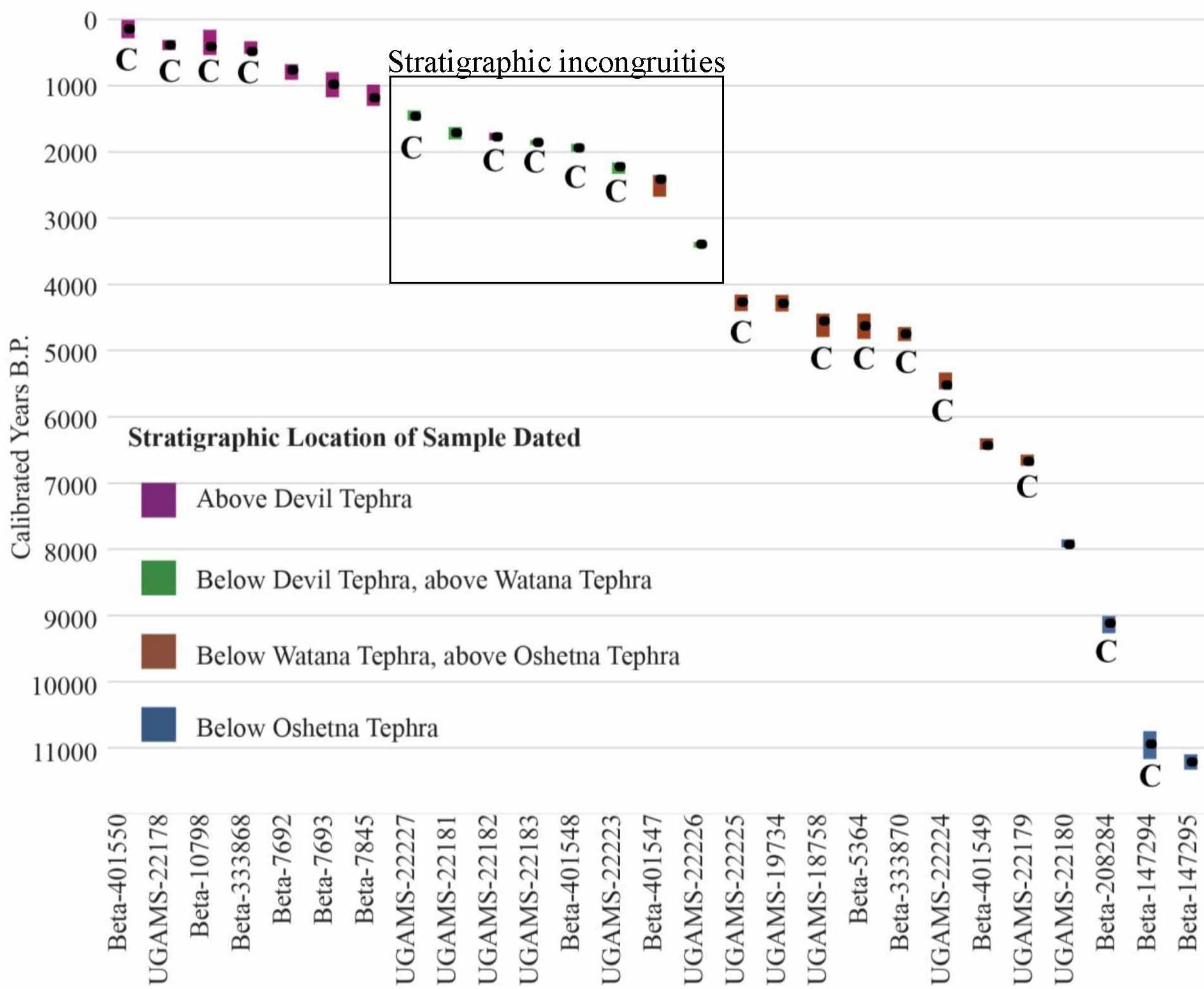


Figure 4.3. Calibrated mSRV cultural component age ranges (2 δ), ordered by calibrated median and stratigraphic position. Horizontal axis is the laboratory number that produced the date (reference Tables 3.3 and 3.4 for sample information); vertical axis is calibrated age range to two standard deviations; dates are grouped by color according to stratigraphic position, calibrated median is denoted by black dot in center of 2 δ range. Calibrated using the IntCal13 terrestrial calibration curve in CALIB Program, version 7.1 (Reimer et al. 2013; Stuiver and Reimer 1993). Inset box highlights stratigraphic incongruities; ranges with "C" beneath indicate cultural component dates; other dates are stratigraphic. For sample information and calibrated 2 σ ranges, see Tables 3.4 and 4.12.

by a lack of tephra samples or detailed descriptions from these locations. However, given the fact that this chronology considers dates produced at different times, by different laboratories, and on different materials, some reversals are to be expected.

Reversals are evaluated relative to when the date was produced (during the 1980s or recently), the laboratory that produced the date, other dates at that stratigraphic position, and whether the date was cultural or stratigraphic (cultural dates, having been recovered from an archaeological site, are treated as having greater potential for exhibiting stratigraphic reversals due to cultural activity occurring on mSRV tephra surfaces). Despite being a stratigraphic date, Beta-401547 (2390±30 ^{14}C yr B.P.) is assumed to be in error because it is younger than both a terrestrial date (UGAMS-22226, 3170±20 ^{14}C yr B.P.) and lacustrine date (UGAMS-18889, 3200±30 ^{14}C yr B.P.) occurring above the Watana tephra. UGAMS-22227 (1540±20 ^{14}C yr B.P.), located stratigraphically below the Devil tephra and with a younger age than dates occurring above the Devil tephra, is also assumed to be incorrect because four other older dates occur at that stratigraphic position (UGAMS-22181, UGAMS-22183, Beta-401548, I-12250) and an older date also occurs above the Devil tephra (UGAMS-22182).

As can been seen in Figure 4.3, notable absences in calibrated cultural dates from the mSRV occur. These absences will be discussed further in Chapter 6, following the presentation of the model for the effects of ash deposition presented in Chapter 5. Dates (both produced as part of this study and previously published and unpublished dates, see Table 3.4) constraining mSRV stratigraphic events are presented in Figure 4.4. Dates bounding the Oshetna tephra suggest that it was deposited between 7090±30 ^{14}C yr B.P. (UGAMS-22180) and 5850±25 ^{14}C yr B.P. (UGAMS-22179). Recent dates indicate that the Watana tephra (both upper oxidized and lower unoxidized) were deposited between 3690±25 ^{14}C yr B.P. (UGAMS-19730) and 3200±25 ^{14}C yr B.P. (UGAMS-18849). Lastly, delimiting Devil tephra deposition proved difficult because of stratigraphic reversals; a suite of dates occurring below the Devil tephra include 1790±20 ^{14}C yr B.P. (UGAMS-22181), 1910±20 ^{14}C yr B.P. (UGAMS-22183), and 1990±30 ^{14}C yr B.P. (Beta-401548), whereas a reliable date above the Devil tephra is 1840±20 ^{14}C yr B.P. (UGAMS-22182).

4.2.2 Bayesian age model results

Bayesian calibration techniques were used to model ^{14}C dates by incorporating additional information about the samples submitted for dating. At site TLM-216, knowledge that multiple dates were produced from the same sample of wood is incorporated to provide the best age estimate. For tephra depositional events, stratigraphic position of samples at multiple sites is considered.

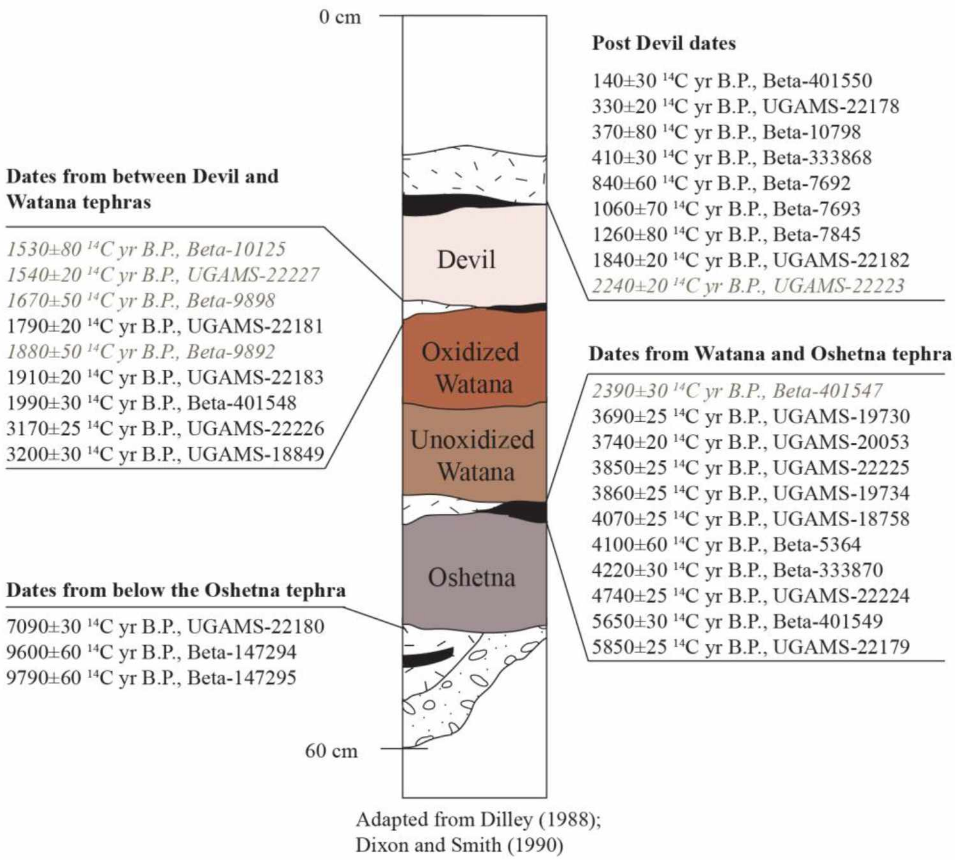


Figure 4.4. Compilation of appropriate existing and new radiocarbon dates constraining stratigraphic units in the mSRV. Italicized/gray dates are considered to be in error. Both terrestrial and lacustrine dates from the mSRV are compiled from Bigelow et al. (2015); Dixon et al. (1985); this study, UAMN (2015); and Wendt (2013). For sample information and calibrated 2 σ ranges, see Tables 3.4 and 4.12.

4.2.2.1 Bayesian calibration of dates from site TLM-216

Fragments of a piece of identified wood (spruce) located between the Devil and Watana tephras were dated as part of Susitna Hydroelectric Project (1979–1985) (Dixon et al. 1985) and yielded a wide range of dates (Beta-9898, Beta-9892, Beta-10125). Because the dates on the wood were used to provide the maximum age for the deposition of the Devil tephra, an additional sample was dated as part of this study (UGAMS-22181). Results of all analyses of the piece of wood are evaluated and indicate that Susitna Hydroelectric Project (1979–1985) dates do overlap with the date obtained as part of this study, however with poor agreement (Table 4.13). Per Oxcal, sufficient agreement should encompass 60% overlap between the two sigma ranges of calibrated dates. However, none of the dates on the piece of wood from TLM-216 encompass 60% of overlap in the two sigma ranges. The modelled age for the piece of wood is from 1620–1725 cal yr B.P., which is within the two sigma range of UGAMS-22181, and

Table 4.13. Problematic dates and Bayesian calibration of the same sample located stratigraphically between the Devil and Watana tephras at site TLM-216 (provides a maximum age estimate of the Devil tephra deposition).

Lab #[a]	Material[b]	^{14}C age years, BP[c]	δ13C,‰[d]	Calibrated age (2 δ)[e]	Calibrated Median[f]	Reference	Modelled age (2 δ), BP[g]	Agreement[h]
Beta-10125	Charcoal	1530±80	-	1293–1434	1592	Dixon et al. 1985	1620–1725	2.7
Beta-9898	Charcoal	1670±50	-	1416–1578	1705	Dixon et al. 1985	1620–1725	35.7
Beta-9892	Charcoal	1880±50	-	1703–1821	1931	Dixon et al. 1985	1620–1725	14
UGAMS-22181	Wood	1790±20	-24.7	1812–1625	1713	This study	1620–1725	97.1

[a]Radiocarbon laboratory number; [b]Material refers to what was submitted for dating; [c]Radiocarbon age in years before present; [d]δ13C, ‰ is the measured ratio of stable carbon isotopes, reported in parts per thousand; [e]Calibrated age range to two standard deviations and [f]median determined using the IntCal13 terrestrial calibration curve in the CALIB Program, version 7.1 (Reimer et al. 2013; Stuiver and Reimer 1993); [g]Modelled age range to two standard deviations, determined using the R_combine tool in Oxcal 4.2 (Bronk-Ramsey 2008, 2009a); [h]Agreement is describes the percent overlap between the modelled age range and the calibrated age range.

therefore that date is considered most reliable, whereas Beta-9898, Beta-9892, and Beta-10125 are omitted (Figure 4.4 appropriately includes UGAMS-22181 and excludes Beta-9898, Beta-9892, and Beta-10125 for that reason).

4.2.2.2 Bayesian calibration for tephra deposition

Radiocarbon data constraining ashfalls in the mSRV and other areas of Cook Inlet were incorporated into a Bayesian model. This model seeks to further constrain the timing of depositional events in the mSRV, by incorporating radiocarbon dates constraining tentatively correlated tephra from areas other than the mSRV. This is purely an explorational model and has several assumptions built into it:

1) Child et al. (1998) identify Oshetna tephra in cores from Wonder Lake and Sneaker Pond (see Figure 2.5); it is assumed that this Oshetna tephra identification is correct, despite only two populations of volcanic glass being identified in the samples. Dates constraining Child et al.'s (1998) lacustrine Oshetna tephra are used to further constrain terrestrial Oshetna tephra deposition in the mSRV.
2) Terrestrial and lacustrine dates from the mSRV underlying and overlying the bulk Watana tephra constrain the timing of Hayes Volcano proximal tephras F and H (Section 4.2 of this chapter).
3) Distal tephra identified in Kenai Peat deposits by Combellick and Pinney (1995) (their T1; Figure 2.5) as being a product of Hayes Volcano are tentatively correlated to Hayes Volcano proximal tephra H by Wallace et al. (2014). This tentative correlation is assumed to be correct to allow the model to consider the timing of

individual Watana tephra sub-units in the mSRV (upper oxidized, and lower unoxidized).

4) Riehle (1985) identifies a tephra younger than the Hayes tephra set H at sampling locality 27 (see Figure 2.5). This sampling locality is in the trajectory of the mSRV and for modeling purposes, Riehle's (1985) tephra is assumed to correlate with the mSRV Devil tephra. The date obtained by Riehle (1985) from below the proximal, young, and potentially Hayes Volcano tephra is used to aid in modeling the Devil tephra deposition.

The first model iteration demonstrated poor agreement between UGAMS-22227 and UGAMS-22223 (discussed in Section 4.2.1); a second model iteration did not include these dates and this model successfully provides age estimates of the deposition of each tephra unit (Table 4.14). The Oshetna tephra is modelled as having been deposited between 6641–6896 cal yr B.P., the Watana (lower unoxidized and upper oxidized) tephras between 3701–4084 cal yr B.P., and the Devil tephra between 1727–1813 cal yr. B.P. The model indicates that the lower unoxidized Watana could have been deposited between 3809–4084 cal yr B.P., whereas the upper oxidized Watana could have been deposited between 3701–3950 cal yr B.P. These events therefore could have occurred in rapid succession, or could have been separated in time by a maximum of 380 years.

4.3 Archaeological analyses

The database of mSRV archaeological components separated by mSRV tephra units may be found in the supplemental file that accompanies this thesis (Table S5, Mulliken_2016_thesis_supplemental). Characteristics of sites by stratigraphic location are show in Table 4.15. Tests for differences in archaeological variables at different stratigraphic locations were not statistically significant and results are presented in Table 4.16; however, these sites (bounded by mSRV tephra units) are discussed relative to their stratigraphic position below.

Only eight cultural components are located stratigraphically below the Oshetna tephra, whereas 22 are located between the Oshetna and Watana tephras, 19 are located between the Watana and Devil tephras, and 40 are located above the Devil tephra stratigraphically. The increase in the number of cultural components occurring after Devil tephra deposition is likely related to the increased visibility of these components due to their younger age and more

Table 4.14. Results of mSRV tephra unit depositional modelling using Bayesian calibration.

Lab #[a]	Site[b]	Stratigraphic Location[c]	^{14}C age, yr B.P.[d]	δ13C,‰[e]	Calibrated age (2 δ)[f]	Calibrated Median[g]	Reference[h]	Modelled age (2 δ), yr B.P.[i]	Agreement[j]
UGAMS-22182	TLM-217	Above Devil	1840±20	-24.9	1713–1825	1775	This study	1712–1797	98.3
UGAMS-22223	TLM-062	Above Devil	2240±20	-25.2	2158–2332	2224	UAMN Archaeology		Poor agreement
Devil Deposition								**1727–1813**	
UGAMS-22227	TLM-216	Below Devil	1540±20	-19.3	1376–1522	1462	UAMN Archaeology		Poor Agreement
UGAMS-22181	TLM-216	Below Devil	1790±20	-24.7	1625–1812	1713	This study	1751–1821	99.6
I-12250	Sampling Locality 25	Tephra 27-A (younger than Hayes set-possible Devil?)	1860±80	-	1605–1987	1791	Riehle 1985	1740–1935	118
UGAMS-22183	TLM-217	Below Devil	1910±20	-25.25	1819–1896	1857	This study	1818–1892	101
Beta-401548	TLM-130	Below Devil	1990±30	-19.2	1879–1997	1940	UAMN Archaeology	1871–1996	96.8
UGAMS-18849	Big Lake	Above Watana (bulk) (F & H)	3200±30	-24	3366–3470	3420	Bigelow et al. 2015	3366–3477	99.9
UGAMS-22226	TLM-184	Above Watana (bulk) (F & H)	3170±20	-25.8	3363–3445	3395	UAMN Archaeology	3364–3446	99.8
Beta-45204	Kenai Peat Deposits, Site A	Above AT1 (Hayes) (Proximal Unit F?)	3470±70	-			Combellick and Pinney 1995	3576–3846	99.7
Beta-45210	Kenai Peat Deposits, Site B	Above BT1(Hayes) (Proximal Unit F?)	3590±70	-			Combellick and Pinney 1995	3641–3891	99.6
Hayes Unit H Deposition								**3701–3950**	**99.7**
Beta-50332	Kenai Peat Deposits, Site A	Below AT 1(Proximal Unit F?)	3510±60	-	3636–3963	3783	Combellick and Pinney 1995	3751–3975	99.8
Beta-50336	Kenai Peat Deposits, Site B	Below AT 1 (Proximal Unit F?)	3540±70	-	3638–4066	3825	Combellick and Pinney 1995	3754–3982	99.7
Hayes Unit F Deposition								**3809–4084**	**99.7**
UGAMS-19730	Clarence Lake	Below Watana (bulk) (F & H)	3690±25	-27.4	3929–4141	4035	Bigelow et al. 2015	3635–4144	99.8
UGAMS-20053	Sally Lake	Below Watana (bulk) (F & H)	3740±20	-28.4	3991–4153	4102	Bigelow et al. 2015	3992–4154	99.8
UGAMS-22225	TLM-046	Below Watana (bulk) (F & H)	3850±25	-24.7	4156–4406	4269	UAMN Archaeology	4153–4339	99.8
UGAMS-19734	TLM-128	Below Watana (bulk) (F & H)	3860±25	-23.2	4160–4409	4288	UAMN Archaeology	4157–4405	99.8
UGAMS-22179	TLM-143	Above Oshetna	5850±25	-24	6568–6740	6672	This study	6529–6777	99.7
CAMS-15637	Wonder Lake Core-WL9	Above FT-2 (Oshetna)	5850±60	-	6497–6664	6664	Child et al. 1998	6568–6740	99.9
Oshetna Deposition								**6641–6696**	**99.7**
CAMS-15642	Wonder Lake Core-WL9	Below FT-2 (Oshetna)	6020±60	-	6679–6865	6865	Child et al. 1998	6743–7141	99.7
CAMS-12292	Sneaker Pond Core-SP16	Below FT-2 (Oshetna)	6060±60	-	6750–6918	6918	Child et al. 1998	6753–7154	99.7
UGAMS-22180	TLM-134	Below Oshetna	7090±30	-24.2	7851–7971	7929	This study	7850–7970	99.8

[a]Radiocarbon laboratory number; [b]State Historic Preservation Office Alaska Historic Resources Survey number for site identification OR descriptive information on where the sample originated; [c]Designates where sample that produced the date came from, relative to informal or formal tephra units; [d]Radiocarbon age in years before present; [e]δ13C,‰ is the measured ratio of stable carbon isotopes, reported in parts per thousand; [f]Calibrated age range to two standard deviations and [g]Calibrated median determined using the IntCal13 terrestrial calibration curve in the CALIB Program, version 7.1 (Reimer et al. 2013; Stuiver and Reimer 1993); [h]Reference the date was obtained from; [i]Modelled age range to two standard deviations, determined using the Sequence tool and the phase, and tau_boundary commands in Oxcal 4.2 (Bronk-Ramsey 2008, 2009a); [j]Agreement is describes the percent overlap between the modelled age range and the calibrated age range.

surficial location. Interesting, seven cultural components are noted by Dixon et al. (1985) to have been dispersed within the Oshetna tephra, whereas one cultural component was noted as being mixed throughout the Watana tephra, and two were noted as being within the Devil tephra.

Generally, the appearance and disappearance of characteristic technologies indicated in the archaeological record of the mSRV coincide with established trends in the general record of central interior Alaska archaeology. Notched points (characteristic of Northern Archaic) appear above the Oshetna tephra and although they are not present in cultural components between the Watana and Devil tephra, it is likely that this is a sampling bias. Microblades and microblade cores are present throughout the stratigraphy of the mSRV, which is to be expected given the recent syntheses that have noted the conservation of this technology throughout the Holocene (Esdale 2008; Potter 2008c). Changes in lithic assemblage richness and density are indicated at different stratigraphic positions (Figure 4.5), with denser and richer lithic assemblages occurring below the Oshetna tephra, perhaps associated with the residential use of the area (and related to the high residential mobility patterns reflected in early to mid-Holocene archaeological assemblages) (Potter 2008c).

Preservation bias is definitely an issue when faunal remains from the mSRV are considered. Small mammals are absent in all stratigraphic positions except between the Devil and Watana tephras and this is likely a taphonomic issue in that the faunal remains of small mammals are less likely to be preserved. Other archaeological components with better faunal preservation from the early Holocene have demonstrated that small mammals were being obtained in upland locations. At the Carlo Creek site in the Nenana River Valley in the central Alaskan Range, for example, arctic ground squirrel, Dall sheep, and caribou remains are preserved (Bowers 1980; Bowers and Reuther 2008). Notably, medium to large fauna are present throughout the archaeological record of the mSRV and caribou specifically are identified at all stratigraphic positions, indicating that this resource was being obtained in the mSRV throughout the Holocene. Interestingly, moose, Dall sheep, and wolf, other medium to large mammals that should also have been preserved (if they were being obtained) throughout the Holocene are absent in all stratigraphic locations except above the Devil tephra. Ptarmigan are also noted at one site located stratigraphically between the Oshetna and Watana tephras.

Table 4.15. Summarized results of archaeological database building by stratigraphic position of components relative to mSRV tephra units.

Stratigraphic grouping of components	Number of components	Percentage of components with characteristic: Notched points	Projectile points	Modified flakes	Microblades or microblade cores	Alluvial landforms	Elevated landforms	Faunal fragments	Small mammal	Medium to large mammal	Identified caribou	Cultural depressions	Fauna notes
Post Devil	40	3	10	38	5	33	68	55	0	25	13	5	Moose and dall sheep identified at TLM-250; wolf identified at TLM-220
Between Watana and Devil	19	0	11	37	5	16	84	53	11	47	37	0	
Between Oshetna and Watana	22	2	14	41	9	23	77	36	0	23	14	0	Ptarmigan identified at TLM-0016
Pre-Oshetna	8	0	25	50	25	13	88	50	0	38	25	0	

Data catalogued from Dixon et al. (1985). Note that notched points are likely to be present between the Watana and Devil tephras, but are not indicated to be in this table because only those archaeological components that were stratigraphically located between the Watana and Devil tephra were considered; many archaeological components were distributed throughout different stratigraphic units as a result of bioturbation and other processes and therefore were not considered in this analysis.

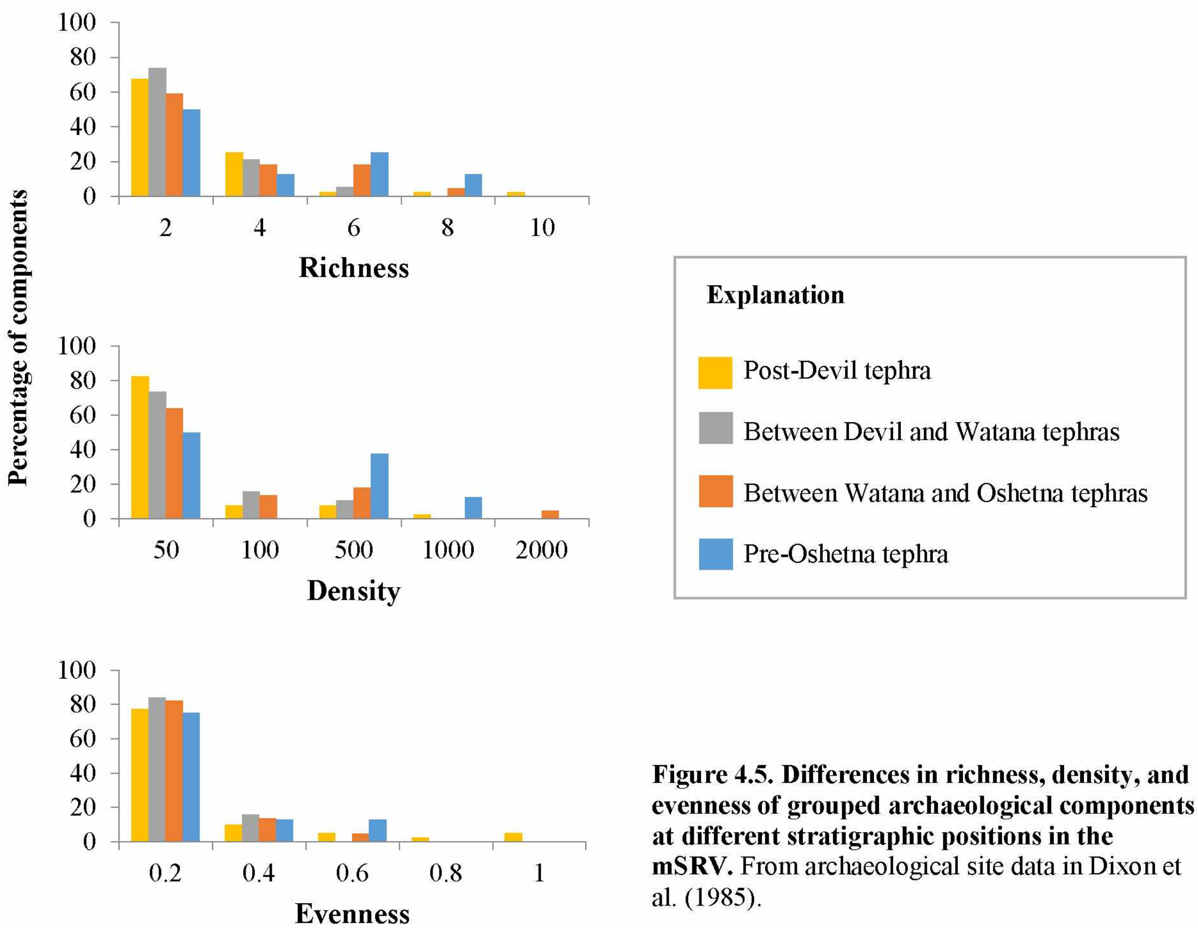


Figure 4.5. Differences in richness, density, and evenness of grouped archaeological components at different stratigraphic positions in the mSRV. From archaeological site data in Dixon et al. (1985).

Table 4.16. Results of Pearson chi-square, Fisher's Exact test, and Cramer's V statistics for association between archaeological components grouped by independent stratigraphic location and landform/lithic types.

Stratigraphic Position	Chi-Square			Fisher's Exact		Cramer's V		Chi-Square			Fisher's Exact		Cramer's V	
Between Groups	Value	Degrees of Freedom	P-value	Exact sig. (2-sided)	Exact sig. (1-sided)	Value	Approx. sig.	Value	Degrees of Freedom	P-value	Exact sig. (2-sided)	Exact sig. (1-sided)	Value	Approx. sig.
Post-Devil/between Devil and and Watana	**Notched Points**							**Projectile Points**						
	0.483	1	487	1	0.678	0.09	0.487	0.004	1	0.95	1	0.637	0.008	0.95
	Landform							**Microblades and Cores**						
	1.82	1	0.177	0.222	0.15	0.176	0.177	0.002	1	0.966	1	0.696	0.006	0.966
Between Devil and Watana/Between Watana and Oshetna	**Notched Points**							**Projectile Points**						
	1.816	1	0.178	0.49	0.282	0.21	0.178	0.092	1	0.762	1	0.572	0.047	0.762
	Landform							**Microblades and Cores**						
	0.312	1	0.576	0.703	0.438	0.087	0.576	0.22	1	0.639	1	0.556	0.073	0.639
Between Watana and Oshetna/Pre-Oshetna	**Notched Points**							**Projectile Points**						
	0.779	1	0.377	1	0.531	0.161	0.377	0.545	1	0.46	0.589	0.405	0.135	0.46
	Landform							**Microblades and Cores**						
	0.384	1	0.536	1	0.48	0.113	0.536	1.285	1	0.257	0.284	0.284	0.207	0.257
Within Groups														
Post Devil: Landform type and lithic types	**Notched Points**							**Projectile Points**						
	0.494	1	0.482	1	0.675	0.111	0.482	2.14	1	0.144	0.284	0.192	0.231	0.144
								Microblades and Cores						
								1.014	1	0.314	1	0.45	0.159	0.314
Between Devil and Watana: Landform type and lithic types	**Notched Points**							**Projectile Points**						
	no notched points at this stratigraphic location							0.419	1	0.517	1	0.702	0.149	0.517
								Microblades and Cores						
								0.198	1	0.656	1	0.842	0.102	0.656
Between Watana and Oshetna: Landform type and lithic types	**Notched Points**							**Projectile Points**						
	0.647	1	0.421	1	0.589	0.171	0.421	1.022	1	0.312	1	0.442	0.215	0.312
								Microblades and Cores						
								0.647	1	0.421	1	0.589	0.171	0.421
Pre-Oshetna Landform type and lithic types	**Notched Points**							**Projectile Points**						
	No notched points at this stratigraphic location							0.381	1	0.537	1	0.75	0.218	0.537
								Microblades and Cores						
								0.381	1	0.537	1	0.75	0.218	0.537

Statistical tests were performed using IBM SPSS Statistics 22 analytical software.

The percentages of cultural components located on alluvial and elevated (kames and eskers) landforms are similar at all stratigraphic locations within the mSRV. Cultural depressions associated with Athabascan components predictably appear only after Devil tephra deposition. The characteristics of mSRV archaeological sites bounded by tephra are discussed further, relative to trends in the archaeological record of interior Alaska, in Chapter 6.

4.4 Summary

This chapter has presented the results of tephra, radiocarbon, and archaeological analyses completed as part of this study. Results indicate that the Devil tephra likely represents a single volcanic event, likely from Hayes Volcano, but which is not found proximal to Hayes Volcano at the Hayes River Outcrop of Wallace et al. (2014). Similarity coefficients calculated between samples of the upper oxidized and lower unoxidized portions of the Watana tephra and the Hayes tephra set H indicate that the tephras are correlative and suggest that the Watana tephras likely represent proximal tephras F and H at the Hayes River Outcrop (Wallace et al. 2014); however, the amount of time between deposition of the two Watana tephra is unclear and archaeological evidence for eolian subunits and paleosols between these two tephra does suggest that some amount of time passed. Analyses of the Oshetna tephra, which could also be a Hayes Volcano product, demonstrate that the deposit contains at least four populations of volcanic glass, and therefore could be the result of a compositionally zoned magma chamber or a re-worked deposit representative of multiple depositional events of unknown origin.

This chapter has also presented a refined chronology for the mSRV, which differs from the mSRV chronology established in the 1980s. The revised chronology indicates that the Devil tephra was deposited between 1625–1825 cal yr B.P., the Watana tephras were deposited between roughly 3360–4400 cal yr B.P., and the Oshetna tephra was deposited between 6570–8000 cal yr B.P. A Bayesian model of calibration, which incorporates *tentatively* correlated tephra in the Cook Inlet and other areas, indicates that the ages of these tephra could be even further refined. This explorational model—which is not meant to be used to delimit mSRV tephra ages—indicates that the Devil tephra could have been deposited between roughly 1740–1890 cal yr B.P.; the Watana tephra as a unit has a modeled age of approximately 3700–4080 cal yr B.P., with the model suggesting that the two subunits could have occurred in rapid succession or could have been separated by a maximum of 380 years; and, the Oshetna tephra could have been deposited between approximately 6640–6700 cal yr B.P.

This chapter has also presented refined dating of cultural components in the mSRV, and there are possibly absences in cultural use of the mSRV following ash depositions. Although statistical tests for differences in archaeological components at specific stratigraphic locations did not display statistically significant differences, consideration of settlement and subsistence systems trends in the archaeological record of central interior Alaska, in conjunction with the refined understanding of the mSRV stratigraphy presented in this chapter, allows for evaluation of how the tephra events could have affected hunter-gatherers utilizing the mSRV. This requires evaluating the potential effects of ashfalls, through consideration of the historic volcanic events, as well as paleoenvironmental and archaeological contexts. A model for the potential effects of ash deposition in the mSRV is presented in Chapter 5; this model is integrated and discussed in along with these results in Chapter 6.

Chapter 5: Volcanic events and their effects: qualitatively modelling the effects of tephra deposition in the mSRV

This chapter will present information on historic volcanic events and their effects in an effort to derive general concepts that may be applied towards understanding the consequences of tephra deposition in the mSRV. The chapter is separated into two sections: Section 5.1 presents a summary of two historic volcanic events in terms of eruption dynamics, deposits, and consequences, with particular attention to the use of these events to understand the effects of tephra deposition in the mSRV; and, Section 5.2 presents a qualitative model for the effects of tephra deposition in the mSRV. Section 5.2 uses concepts and generalizations outlined in Section 5.1 and incorporates physiographic information on the mSRV, paleoenvironmental and successional data from central interior Alaska and the mSRV, and ethnographic and archaeological data on hunter-gatherer subsistence resources.

5.1 Eruption dynamics, deposits, and consequences

The effects of some explosive volcanic events in historic times have been documented closely, allowing for these events to be used, much like ethnographic analogies that inform interpretation of archaeological remains, in an attempt to understand prehistoric eruptions and their potential effects on the environment and prehistoric populations. However, although the impacts of other eruptions may be well-known, both the sizes of the eruptions and the environmental settings are different, making them not directly analogous to the Hayes Volcano eruptions resulting in ash deposition in the mSRV. Therefore, the limitations of applying concepts on the effects of previously documented volcanic events to aid in understanding the effects of tephra deposition in other areas need to first be outlined. This section is separated into two subsections: Subsection 5.1.1 outlines potential disconnects between historic volcanic events and their use to understand Hayes Volcano eruptions and tephra deposition in the mSRV; and, Subsection 5.1.2 outlines general concepts of these historic volcanic events that may be used to understand tephra deposition in the mSRV.

5.1.1 Using volcanic events as analogs: potential disconnects

There is no perfect analog for understanding the effects of tephra deposition in the mSRV for a number of reasons. First, all explosive volcanic events are not analogous and vary in many dimensions including the volume of products, the height of the eruption plume, and the thicknesses of resulting deposits (Lockwood and Hazlett 2010). The Volcanic Explosivity Index, however, offers a logarithmic scale (values range from 0–8) to compare different events relative qualitative and quantitative factors including eruption magnitude, intensity, destructiveness, or dispersive power (i.e. a VEI of 5 is ten times more powerful than a VEI of 4) (Newhall and Self 1982). Second, these varied volcanic events have occurred at different times of year in different environments and have affected different ecosystems, each with their own unique dynamics, in different ways. Third, many volcanic events with documented effects have been proximally focused, providing information on the effects of tephra deposition in the areas located close to the volcanic vent, but lack information on the effects of tephra deposition in the distal environment. However, despite these important differences, this study seeks to obtain general concepts from studies on large eruptions such as Mount St. Helens in 1980 and Novarupta-Katmai in 1912 that may be used in an effort to understand the *potential* effects that tephra deposition had in the mSRV; each eruption will be briefly summarized below.

The 1980 eruption of Mount St. Helens is one of the most well-known plinian eruptions in recorded history, with a VEI of 5 (Newhall and Self 1982). The eruption was preceded by earthquakes increasing in magnitude over the two months leading up to the May 18 north flank collapse and subsequent debris avalanche, directed blast, pyroclastic flows and lahars. Figure 5.1 displays the vertical eruption plume that also formed, resulting in ash fallout in a primarily northeast direction (Swanson and Major 2005). The resulting tephra deposit had a volume of 1.1 km^3 and covered a geographically extensive area of 1000 km^3 (Dale et al. 2005; Swanson et al. 2005). The area that experienced ash fallout from the eruption was alpine and subalpine, and notably the eruption occurred before new plant foliage had emerged (Swanson and Major 2005). An extensive body of literature exists on the effects of the 1980 eruption of Mount St. Helens eruption, with areas of specific tephra thickness being revisited during years following the eruption with plant species survival and recovery being documented (Dale et al. 2005).

The Novarupta-Katmai eruption of 1912 is the largest eruption on earth during the twentieth century and it, too, offers a though-provoking comparison for the Hayes Volcano eruptions thousands of years earlier. The eruption had a VEI of 6 (Newhall and Self 1982), making it 30 times more powerful than the 1980 Mount St. Helens eruption thus greater impacts

Figure 5.1. Eruption plume of the May 18, 1980 plinian eruption of Mount St. Helens. From USGS.

likely occurred. The eruption, which started on June 6, actually consisted of three plinian eruptions from Novarupta, on the Alaska Peninsula, that resulted in a collapsed caldera (one of very few historical eruptions to do so) at Katmai, 10 km east (Hildreth and Fierstein 2012). In total, 17 km^3 of fall deposits occurred over a period of approximately 60 hours (Hildreth and Fierstein 2012). The eruptions were preceded by earthquakes that increased in frequency and magnitude (up to 14 between magnitude 6.0 and 7.0) over about five days prior to the first eruption plume being sighted, which led indigenous groups at Katmai Village to evacuate the area (Hildreth and Fierstein 2012). The largest of the three plinian eruptions, which was about 70% of the volume of the total eruption, was large enough to be heard 1200 km away in Juneau, and occurred simultaneous with ignimbrite emplacement in the Valley of Ten Thousand Smokes. It was followed within hours by the two smaller plinian eruptions (4.8 km^3 and 3.4 km^3) and pyroclastic density currents (Hildreth and Fierstein 2012). In total, there are eight regional layers of fallout associated with this eruption, three which are present at Kodiak Village, 170 km downwind (Hildreth and Fierstein 2012) (Figure 5.2). Volcanic ash fallout from the Novarupta-Katmai eruption was primarily in an easterly direction, and following the eruption, habitants of

Figure 5.2. Ashfalls at Kodiak village, 170 km downwind from Novarupta vent. Photo by Wilbur J. Erskine, in Hildreth and Fierstein (2012).

Kodiak Island experienced respiratory distress and eye complications, and coastal settlements near Katmai were abandoned (Griggs 1915). Although the 1912 Novarupta-Katmai eruption is well-studied, comparison of it with Hayes Volcano late Holocene tephra set is unrealistic because of the great difference in size and timing of the eruptions. However, Robert Griggs documented the effects of the Novarupta-Katmai tephra deposition on distal Kodiak Island vegetation by revisiting specific stations from 1913–1916 (Griggs 1915, 1918, 1919, 1933), and this information is useful for understanding the effects of tephra deposition in distal environments.

Studies on large volcanic eruptions have contributed greatly to understanding how the environment is changed as a result of the volcanic events, and how it continues to change for decades afterward; however, one of the problems in applying concepts on the effects of these eruptions to understand tephra deposition as a result of Hayes Volcano eruptions is the fact that this volcano has not been heavily investigated. Section 2.2.3 summarizes the current understanding of Hayes Volcano eruptions and eruptive products. Although its last eruptive phase, which consisted of explosive plinian-style eruptions, is currently understood to have extended from 3600–4400 cal yr B.P., evidence suggests that Hayes Volcano had both an older eruption and younger eruption (Riehle 1985; Wallace et al. 2014; Waythomas and Miller 2002).

The 3600–4400 cal yr B.P. eruptive phase is represented by the Hayes tephra set H and Watana tephras in the mSRV. Riehle et al. (1990) estimate that eruptions producing the Hayes tephra set H could have had a total eruptive volume of 10 km^3, with each individual tephra representing 1.25 km^3; however, in reality, each individual deposit likely varied in volume. This study suggests that two of eruptions producing the Hayes tephra set H were large enough to deposit tephra in the mSRV, 240 km from Hayes Volcano; however, there are currently no constraints on the timing of each individual member of the Hayes tephra set H, which prevents a comprehensive understanding of the magnitude of the 3600–4400 cal yr B.P. eruptive phase. Were these tephra deposited in rapid succession or do these tephra represent individual discrete events? These two scenarios have different implications for estimating the VEI of the event/events. In addition, the potentially younger and older Hayes Volcano eruptions, which may be represented by the Oshetna and Devil tephra deposits in the mSRV, have not been investigated and are thus poorly understood

Despite gaps in understanding Hayes Volcano, and historic volcanic events differing along a spectrum ranging from the events themselves to the environments of tephra deposition, this exercise seeks to control for these differences by using information on tephra deposit thickness and plant types affected. Tephra deposit thickness is known for both the historic volcanic events and for the tephra deposits in the mSRV, and may be used as a means to extrapolate effects of tephra deposition as result of historic eruptions to understanding the effects of tephra deposition in the mSRV. Likewise, the environments affected by other volcanic event tephra depositions differ from the mSRV: the Mount St. Helens 1980 eruption deposited tephra in alpine and subalpine ecosystems of Washington state, whereas the effects of 1912 Novarupta-Katmai tephra deposition were documented on Kodiak Island, a distal environment ranging from coniferous forest to grassland to lowlands and coastal areas and with an overall maritime climate (Griggs 1915, 1918). The mSRV is a marginal upland area on the fringe of marginality (see Section 2.1.3 for a description of the mSRV), and the implications of tephra deposition therefore would have been very different for resources there, and for hunter-gatherers relying on those resources. The plant species presently growing in the mSRV are known and paleoenvironmental data provide a means to estimate which plants were growing there throughout the Holocene. The effects of tephra deposition on specific plant types in other environments have been documented and offer a means to estimate how plants in the mSRV may have been impacted by tephra deposition. In addition, information on successional processes in Alaska offers a means to understand how environmental disturbances could potentially have impacted species composition in the mSRV.

VanderHoek and Nelson (2007) also highlight that the season of a volcanic eruption is an important consideration. The season of deposition of Hayes Volcano tephra is not known. Both the Mount St. Helens 1980 and 1912 eruption of Novarupta-Katmai occurred during the warm season, before and after foliage emergence, respectively. Snow was still present on the ground in some areas of Mount St. Helens 1980 tephra deposition, allowing for the effects of snow cover to be qualitatively considered. Other volcanic eruptions resulting in tephra deposition on snow are also incorporated in the discussion, however, to more thoroughly consider the impact of tephra deposition on snow. Lastly, the effects of tephra deposition on animals are documented for the Mount St. Helens 1980 eruption; however, the emphasis of Mount St. Helens studies is on vegetation. Therefore, to supplement the Mount St. Helens data, information on the effects of tephra on animals from volcanic eruptions in other areas, including New Zealand and Iceland, are considered in this exercise.

5.1.2 Consequences of tephra deposition

This section will discuss the effects of tephra deposition as a result of historic volcanic eruptions, the limitations of which have been outlined above. Generally, the effects of tephra deposition depend on the depth, texture, and frequency of deposition, which will impact how tephra affect plants, animals, and soils (Antos and Zobel 2005). This section may be separated into three broad areas: the first considers the effect of tephra deposition on plants, the second summarizes the effect of ashfalls on animals, and the last briefly discusses the impacts of tephra deposition on soils.

Despite different types of eruptions occurring in different environments, the impacts of tephra deposition on vegetation are consistently affected by the depth of tephra deposition and the season of tephra deposition. Studies on Mount St. Helens and Kodiak Island have demonstrated that the thickness of the tephra deposit influences plant species survival: as the tephra deposit increases in thickness, so does the range of plants that are affected negatively (Antos and Zobel 2005; Griggs 1915). Although the forest canopy was not substantially altered due to Mount St. Helens 1980 tephra deposition, bryophytes (non-vascular plants) and shrubs were, with tephra deposit depth being most influential on the amount of damage inflicted (Antos and Zobel 2005). All moss and bryophytes were killed by 4.5 cm of tephra deposition, whereas most herbs survived. Tephra deposits of 15 cm, though, killed moss, bryophytes, herbs, and shrubs (Antos and Zobel 2005). Bryophytes took the longest time to recover after the 1980 Mount St. Helens eruption, approaching the pre-eruption cover roughly 20 years following the eruption, with differences in species composition, however (Antos and Zobel 2005). Herb cover had recovered within a couple years in areas of 4.5 cm of ashfall, but was still low 20 years later in areas with 15 cm of ash fallout (Antos and Zobel 2005). Plant growth form greatly affected changes in species compositions, as clonal species with ground stelons (horizontal growth) and species that regularly flowered and produced many seeds spread more rapidly following Mount St. Helens 1980 tephra deposition (Antos and Zobel 2005).

Likewise, on Kodiak Island, areas with thick spruce forests offered some protection to understories of mosses, shrubs, and herbs, and the spruce canopies were large unaffected by tephra deposition (Griggs 1915). However, understories were exposed to tephra deposition in areas with less spruce and in lowlands with predominantly grasses, shrubs, and herbs (Griggs 1915). Species that were buried and not capable of penetrating the ~5–28-cm-thick tephra deposit did not survive, whereas those species that were able to penetrate the tephra (woody plants such as willows) and grow ground stelons were most successful in the years following the 1912 Novarupta-Katmai eruption. Notably, fireweed and grasses were able to colonize tephra deposit surfaces within a year of deposition on Kodiak Island and likely generated many flowers and seeds (Griggs 1915, 1918) (Figure 5.3). Horsetail also flourished on top the tephra surface in areas it had not been dominant before due to the production of lateral ground stelons that allow the plant to rapidly spread on top tephra surfaces (Griggs 1915). Griggs (1915) also notes that lichen growing on trees were blackened and killed on Kodiak Island. Slopes and cracks in tephra surfaces played a role in vegetation survival and recovery: tephra particles were more easily eroded away from steep slopes within a year of tephra deposition, leaving plants less affected and able to recover more rapidly, and cracks in tephra surfaces allowed plants to grow in the years following the eruption (Figures 5.4 and 5.5) (Griggs 1918).

Season of deposition also plays a part in plant survival. Antos and Zobel (2005) note that the timing of the 1980 Mount St. Helens eruption in May was crucial, as new shoots had not yet emerged from the ground and plants had not yet foliated; despite tephra deposition, woody

Figure 5.3. Rapid plant recovery on Mount St. Helens. Fireweed grows through tephra weeks after the May 18, 1980 Mount St. Helens eruption. Photo by Jerry Franklin, U.S. Forest Service.

species were able to foliate normally. Contrarily, the Novarupta-Katmai eruption of 1912 occurred shortly after plants had foliated, thus delicate new leaves were more susceptible to direct damage from tephra, which includes impact damage, impediment to leaf gas and energy exchange, and defoliation (Antos and Zobel 2005; Griggs 1915). Many plant species that had initially appeared dead, however, had only been defoliated and were recovering by 1915 (Griggs 1915; Hildreth and Fierstein 2012). Tephra deposition may also be detrimental in the form of toxic leachate that damages roots, or it may alternatively be a source of nutrients for plants (Sheets and Grayson 1979). Importantly, precipitation (which is also affected by the seasonality of the eruption) impacts the tephra deposit and its effect on plants, as fine-ash can harden when wet, resulting in a surface that is resistant to water and plant growth (Antos and Zobel 2005).

The literature on the effects of ash deposition demonstrate contrasting information on the effect of snow, with some studies suggesting it can protect plants from negative impacts of tephra deposition (Antos and Zobel 2005; VanderHoek and Nelson 2007), while others suggest tephra deposition on snow can make it more difficult for plants to grow through (Antos and Zobel 1992). These differences are likely related to the depth of both the snow the tephra are deposited on, as well as the thickness of the tephra deposit itself. Indeed, after the Hekla eruption of 2000 in Iceland, snowpack covered by 15 cm of tephra remained frozen for up to 15 months in some sheltered areas (Kellerer-Pirklbauer et al. 2007). Antos and Zobel (2005) note that plants

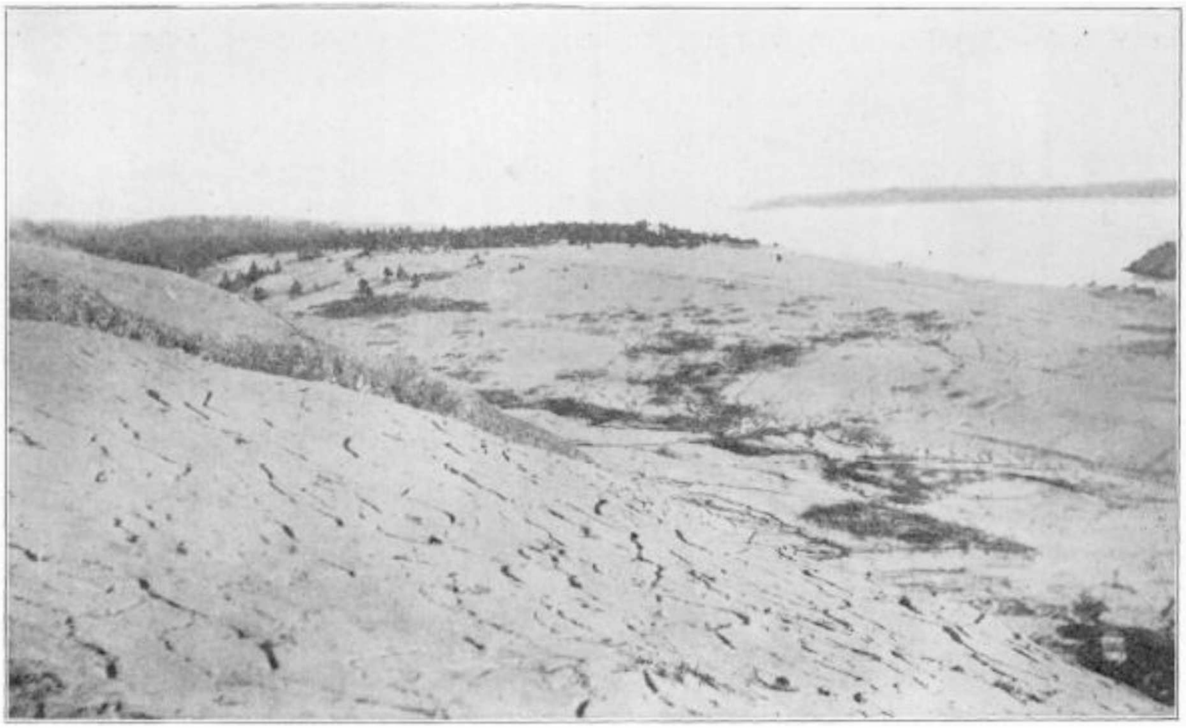


Figure 5.4. Ash covered hillside on Kodiak Island, 170 km downwind from Novarupta. Photo taken approximately four months after the June 1912 eruption, by M.D. Snodgrass, in Griggs (1918).

Figure 5.5. Plant recovery on Kodiak Island, three years after the 1912 Novarupta-Katmai eruption. Hillside is the same as pictured in Figure 5.4, vegetation is primarily grass; photo by B.B. Fulton, in Griggs (1918).

beneath snowpack experienced damage more often than shrubs and small trees that were in areas without snowpack because the weight of the mantled tephra after snowpack melt prevented stem penetration of the tephra layer. Shrub cover after the Mount St. Helens 1980 eruption was most related to whether there had been snow at the time of the eruption: where 15 cm of tephra had been deposited on snow, shrub cover was still low 20 years later. Alternatively, VanderHoek and Nelson (2007) suggest that snow offers protection for plants and small animals.

The effect of tephra deposition on small mammals is not emphasized in the literature. At Mount St. Helens, most small animals survived in areas inundated by tephra and these species influenced the rate and pattern of biological succession (Crisafulli et al. 2005). Vegetation under snow and tephra deposited by the 1980s Mount St. Helens eruption provided uncontaminated sustenance for small mammals and these areas became biological hot spots of production, with small mammals disturbing the tephra deposit and making plant growth easier compared to the surrounding areas more drastically affected by tephra deposition (Crisafulli et al. 2005).

Ingestion of plant matter contaminated by tephra can be problematic for a number of reasons, and is one of the dangers to animals in an area affected by tephra deposition. Sheep and cattle exposed to tephra from Ruapehu Volcano, in New Zealand, experienced death due to starvation and tephra toxicity from ingestion of chemicals absorbed onto tephra surfaces, which may include fluorine, sulfur, and chlorine (Cronin et al. 1997; Oskarsson 1980; VanderHoek and Nelson 2007). Fluorine ingestion specifically can result in chronic fluorosis, which can cause death in ruminants, especially juveniles (Cronin et al. 2003; Rubin et al. 1994). Furthermore, Cronin et al. (1997) demonstrate that grazing animals can be affected by chronic or rapid acute fluorosis when ingesting toxic elements in tephra or water contaminated by it, or by starvation when grazing areas are blanketed in as little as 2–3.5 mm of tephra; juveniles or animals in the late-stages of pregnancy are especially at risk. Ingestion of tephra may additionally abrade teeth resulting in pitting (Oskarsson 1980; VanderHoek and Nelson 2007). Tephra contamination of water sources in an area can have an impact on terrestrial mammals as well as riverine and marine resources. Salmon populations starved, suffocated, and failed to spawn as a result of the 1912 Novarupta-Katmai tephra deposition; however, spawning had recovered by 1920 (Hildreth and Fierstein 2012).

The impact of tephra deposition on soils also has contrasting impacts. Volcanic products are often cited as a source of nutrients, which may rejuvenate an established soil (Sheets and

Grayson 1979). Indeed, Griggs (1918) notes that only two years after deposition of the 1912 Novarupta-Katmai tephra, grass and berries on Kodiak Island grew earlier in the year and in greater abundance than had been seen before (seeming to attribute it to added nutrients from tephra deposition). However, tephra deposits that harden after becoming wet create a surface that is resistant to water, effectively blocking water and nutrients from reaching the underlying soil (Antos and Zobel 2005; Wilcox 1959). Extensive tephra deposition in an area, which kills much of the vegetation, may begin formation of a new soil that is derived from the tephra deposit (Ugolini and Zasoski 1979). Because tephra have large surface areas, the ability to retain water, and easily weatherable elements such as aluminum and iron, they are particularly susceptible to pedogenesis; tephra-derived soils have been described in southcentral and southeast Alaska (Ping et al. 1989).

In summary, tephra deposition depth and the season of eruption have profound influences on plants within an ash fallout area and plant form is also an important factor in re-colonization of the tephra surface, as those plants able to penetrate tephra and grow ground stelons are initially most successful in the years immediately following an eruption. Importantly, bryophytes are severely damaged by as little as 2–4.5 cm of tephra deposition, which has ramifications for considering how tephra deposition affects those species that rely on bryophytes. Tephra deposition also directly impacts animals, with ingestion of tephra being especially problematic for juveniles and pregnant females. The seasonal timing of tephra deposition therefore also has implications for the impact of tephra deposition on an environment. These generalizations may be used in an attempt to qualitatively consider how the mSRV environment may have responded to tephra deposition.

5.2 Understanding the effects of tephra deposition in the mSRV

Studies on the effects of ash deposition inform consideration of the effects of ash deposition in the mSRV. Importantly, the mSRV is a distal location and a patchy upland environment on the fringe of marginality for many resources. While initial ash deposition would have erased existing patches to a certain degree, erosion of ash units and successional processes following ash deposition would have re-established and rearranged patch structures in the mSRV.

Studies on the effects of ash deposition have demonstrated that thickness of the deposit very much dictates which plants survive and are able to re-colonize the area affected by ash deposition (Antos and Zobel 2005; Griggs 1915), which has an effect on those species of animals relying on plants in the area, as well as hunter-gatherers exploiting both plant and animal resources. At Mount St. Helens, bryophytes were unable to survive 4.5 cm or more of ash deposition, whereas shrubs and herbs were able to grow through ash deposits of 4.5 cm (Antos and Zobel 2005). Ash unit thicknesses varies in the mSRV: the Oshetna tephra is generally from 3–5 cm thick, but up to 8 cm thick, the lower unoxidized Watana tephra ranges from 1–10 cm, the upper oxidized Watana from 5–10 cm, and the Devil ranges from 3–5 cm in thickness. Therefore, the effect of Oshetna, Watanas, and Devil depositions on vegetation may have varied as well.

5.2.1 Tephra preservation in the mSRV

Ash preservation on the landscape varies as a function of slope and fluvial processes, and ash preservation in the mSRV is most likely in the same areas as archaeological sites: areas with slopes less than 15 degrees, below 1500 m elevation, and areas that are sheltered (Romick and Thorson 1983). In locations with slopes greater than 15 degrees, above 1500 m elevation, and with less shelter, the tephra would have been transported and reworked by slope processes, possibly rapidly after it had been deposited (Collins and Dunne 1986). These differences in preservation of tephra as a function of slope would have also been affected by vegetation, and would have affected vegetation survival.

At the time of all ash depositions in the mSRV, spruce had already colonized and become established on the landscape. However, the elevation at which spruce were located likely varied through time relative to changes in the climate (Bigelow et al. 2015; Rohr 2001). Areas populated by spruce and deciduous tree species would have offered some protection for understories of shrubs, sedges, and bryophytes from being completely buried by tephra, thus increasing the likelihood of their survival. As opposed to areas populated by spruce and other trees, upland areas with vegetation consisting primarily of shrubs and bryophytes, which is much of the mSRV, would have been more adversely affected by ash deposition. Whereas woody shrubs would have been capable of surviving ash deposition of up to around 5 cm, bryophytes would have been completely buried and unable to penetrate tephra for re-colonization on the surface.

A combination of tephra erosion processes, as well as vegetation characteristics, would have therefore also affected how tephra deposition impacted the landscape, in addition to the season of tephra deposition. On slopes, in particular, a tephra deposit would be more susceptible to erosion; given the physiographic character of the mSRV, with numerous undulating kame and esker deposits, tephra deposits were very likely to be preserved on the tops of these landforms, but eroded from their slopes, contributing to patchy landscape. Depending on how soon erosion occurred, plants on slopes would be more likely to recover rapidly if tephra were eroded from the surface. On the tops of landforms, however, understories would have been more greatly affected by tephra deposition and lack of erosion. In both instances, if bryophytes were covered by a tephra deposit of more than a couple of centimeters, they would not have been able to survive due to their inability to grow through the deposit. Contrarily, shrubs and herbs may have been able to survive and grow through 4.5 cm thick ash. Given the variability of the tephra deposit thickness in the mSRV, and the variable preservation of the tephra deposits on the landscape, a very patchy vegetation structure would have ensued, with vegetation recovery following general vegetation successional patterns derived from historical observations in Alaska.

5.2.2 Vegetation succession in Alaska

Ecological succession is a concept that describes the processes and patterns of changes in species abundances in a particular area, which occur in response to a disturbance in the environment. Successional processes are unique depending on the initial conditions, such as elevation, soil characteristics, temperature, and precipitation, in addition to the type of disturbance, timing of the disturbance, types of vegetation and species available for colonization. A goal of successional studies is to be able to make generalizations based on similarities and differences in patterns and processes across space and time (McCook 1994). Typically, successional changes in species abundances depend on characteristics of each species, such as maximum size and age, shade tolerance, growth rates, and dispersal abilities (McCook 1994). In Alaska, the sequence of vegetation successional stages has been established from historic observations, with numerous sources for ecological disturbance, such as fire, flooding, ice scour, wind, browsing, stem bending, and also volcanic eruptions, and multiple successional pathways that occur in response to different disturbances and on different types of substrate (Helm and Collins 1997). Different forms of disturbance may not affect all plant species equally, but rather may rejuvenate some species while hampering others through processes such as surface erosion, deposition, and stem bending (Helm and Collins 1997).

Different environmental disturbances result in the creation and cultivation of a patchy landscape in Alaska, consisting of a discontinuous mosaic of heterogeneously distributed resources. Patches within the environment vary in size depending on the scale of the disturbance, and affect the distribution of plants and the animals that rely on them; prehistoric hunter-gatherers therefore would have also been affected by such disturbances, relying on both plants and animals for subsistence. In the boreal forest of Alaska, general vegetation succession following a fire has a pattern of initial grasses, sedges, forbs, and shrubs, which grow to dominate the landscape. However, eventually, deciduous shrubs and trees and coniferous species may grow (Nelson et al. 2008). In the Susitna River Valley floodplain, substrate has an effect on the initial vegetation succession, with horsetail occurring first in silty areas, willow on medium textured areas, poplar on sandy areas, and yellow dryas on cobbly areas (Helm and Collins 1997; Walker 1986). Intermediate succession is dominated by alder, which creates a canopy that is eventually overtaken by poplar with an exceeded grazing height of moose, and browsing initially inhibiting poplar growth. Later stage succession is characterized by thinning of poplar forests, with white spruce understories and birch colonization that eventually transitions to paper birch and white spruce forests with well-developed shrub understories (Helm and Collins 1997).

In the mSRV, species with ground stelons, such as horsetail, and species including fireweed and other lupines would have been able to colonize tephra in areas that it was preserved, as occurred on Kodiak Island following the eruption of Novarupta-Katmai in 1912 (Griggs 1915; Hildreth and Fierstein 2012). According to the general patterns of succession in Alaska, grasses, sedge, forbs, and shrubs would have followed in the years after tephra deposition (Nelson et al. 2008). For species that were affected by initial tephra deposition, such as de-foliated plants or herbs that were buried and not able to grow through the tephra within the first year after deposition, recovery could have occurred within a few years following the eruption, as demonstrated on Kodiak Island following the 1912 eruption of Novarupta-Katmai (Griggs 1915; Hildreth and Fierstein 2012). For bryophytes, and lichens, however, recovery could have taken much longer. Research comparing recovery of over-grazing of lichen to recovery of lichen from forest fires suggests that lichen recovery rates can be very variable; if viable lichen fragments survive in an area, such as may occur as a result of over-grazing, full recovery can take 20 years, whereas if lichen in an area is completely decimated, such as occurs during a forest fire, full recovery can take more than 80 years (Collins et al. 2011; Henry and Gunn 1991). Lichen survival following tephra deposition would depend on the thickness of the tephra, how quickly tephra was eroded from slopes, and if trees and canopies offered enough protection from complete burial of lichen. However, Griggs' (1918) observations that even lichen growing on trees were killed as a result of the Novarupta-Katmai ash deposition suggests that lichen are particularly sensitive to tephra, even if not completely buried beneath a tephra deposit.

5.2.3 Seasonal considerations of tephra deposition in the mSRV

Season of deposition is unknown for the tephra deposits in the mSRV. Historic ash depositional events and general concepts of succession in interior Alaska allow for a model of understanding how volcanic ash deposition affected plants and animals in the mSRV depending on the season (Table 5.1). Deposition of tephra during winter would have blanketed snow surfaces, even perhaps temporarily altering albedo in areas of deposition, and subsequent snow falls would have sandwiched tephra between snow fall events. Ash deposition greater than 1–2 cm on snow has been demonstrated to decrease sub-tephra snow ablation rates; in areas with permafrost, tephra that is thicker than the snow beneath it will insulate the snow and preserve it for longer. Tephra deposition on snow covering bryophytes and shrubs could have prevented their growth and survival the following spring (Antos and Zobel 2005). Depending on how soon snow fell following tephra deposition, however, it could have beneficially prevented ash from being re-suspended in the air for longer periods of time (Griggs 1915; Kellerer-Pirklbauer et al. 2007), decreasing the physiological impact on animals in the area.

Mammals such as wolves, coyotes, foxes, and moose utilize the upland areas such as the mSRV during winter, and ash deposition may have resulted in inhalation and ingestion of ash particles, which can be detrimental to health. However, as the contrasting literature on the effects of tephra deposition on snow indicates, ashfalls during winter in the mSRV may have alternatively protected plants and provided less contaminated sustenance for animals. Because caribou and sheep are grazers, however, a winter diet consisting predominantly of lichen would

Table 5.1. Potential seasonal implication of tephra impact on distal plants, animals, and people in the mSRV.

Season	Resources[a]	Plants relied on[a]	Tephra deposition effects on plants[b]	Ethnographic behavior, potential implications of tephra deposition[c]
Winter	Caribou, sheep	Lichens, sedges, shrubs	Lichens buried by tephra; sedges and shrubs partially buried: mSRV resource poor for caribou/sheep. Potential lichen death depending on deposit thickness, potentially possible for sedges and shrubs to grow through tephra in spring. Twigs coated in volcanic ash necessitated ingestion.	Lowland winter congregations, relying on stored/cached resources supplemented by small mammals, moose. Although ethnographic data suggests little direct affect of tephra due to reliance on stored resources in winter, tephra deposition may have caused resource shortages the subsequent spring.
	Moose	Willow, birch, aspen twigs		
Spring (Calving)	Sheep, caribou, small mammals	Lichens, sedges, shrubs; wide variety of plants	Timing of ash fall crucial. Tephra on new leaves/shoots increases likelihood of plant defoliation and tephra ingestion. Tephra deposition before leaf growth less detrimental, as leaves would still be able to grow and would lack tephra coating (less detrimental to animals); although lichens would be buried and sedges/sbrubs partially buried.	Starvation period: transitioning out of lowland winter settlements, relying on stored resources. If tephra fall occurred prior to leaf growth, plant & animal resources less affected; tephra fall after leaf growth may have detrimentally affected plant and animal availabilities, decreasing yields and prolonging starvation period.
	Ptarmigan	Willow		
Summer	Moose	Birch, willow, aspen, leaves and twigs, forbs	Similar to effects of tephra deposition during spring, after growth of new shoots and leaves. Tephra on leaves may have caused plant defoliation and ingestion of ash; less resource availability to animals.	Fishing camps: dip nets in glacial streams, supplemented with stored resources. Fish die off/failure to spawn from tephra, reduces ability to acquire surplus resulting in prolonged starvation period the following year.
	Sheep, caribou, mall mammals	Willow leaves, sedges, flowers, mushrooms		
Fall	Caribou, sheeps, small mammals	Lichens, sedges, shrubs	Lichens buried by tephra,; sedges and shrubs partially buried. Lichen burial causes lichen death; sedges and shrubs could have grown through tephra in spring .	Hunting camps in upland areas to acquire caribou, sheep, moose, non-anadromous fish, berries. Upland resource procurement suggests hunter-gatherers would have been directly affected, with respiratory and eye discomfort. Plant harvests likely lowered due to tephra fall, and may have resulted in ingestion of ash. Animal availability potentially lower, resulting in lower hunting yields and prolonged starvation period the subsequent spring.
	Moose	Willow, birch, aspen twigs		
	Ptarmigan	Berries		

Synthesis of information on impact of ashfall on animal resources, seasonal patterns of animal and human use of uplands such as the mSRV and the implications of ashfalls for hunter-gatherer resource acquisition. [a]Information on species feeding ecology gathered from Alaska Department of Fish and Game (2015); [b]Effects of ash deposition on plant and animal species inferred from Antos and Zobel (2005), Collins et al. (2011); Cronin et al. (1998, 2003); Griggs (1915); Henry and Gunn (1991); Hildreth and Fierstein (2012); Rubin et al. (1994); Waythomas and Miller (2002); [c]Seasonal ethnographic model of resource procurement patterns adapted from Potter (1997). Note that ethnographic data and archaeological data indicate differing uses of the mSRV, with archaeological data likely indicating multi-season use of upland areas (Potter 2008c), as opposed to ethnographic seasonal use.

have facilitated detrimental ingestion of ash and lichen burial underneath ash would have impeded access (Cronin et al. 1997). Eventually, tephra would be deposited on the ground surface after snow melt and the process of snow melting could make a tephra deposit irregular, with cracks, surface irregularities and variations in thickness (Antos and Zobel 1982; Kellerer-Pirklbauer et al. 2007). Irregularities and cracks in the ash deposit would have facilitated colonization of plants the subsequent spring (Griggs 1918); however, bryophytes buried beneath more than a couple centimeters of ash would have been unlikely to survival to the following spring, which may have affected longer-term availability of lichen to sheep and caribou (Antos and Zobel 2005; Collins et al. 2011; Henry and Gunn 1991).

Caribou herds in Alaska today have been documented as being very sensitive to changes in weather and availability of resources, sometimes traveling greater than normal distances in order to escape bad weather or reach areas with better resources (Alaska Department of Fish and Game 2015). The Nelchina Caribou Herd, for example, expanded its winter range by 100 km in the 1990s to reach areas of greater lichen availability (Collins et al. 2011). Given the length of time taken for lichen to recover from forest fires, and the likelihood of lichen not being able to survive tephra deposition, it is likely that changes to resource availability in the mSRV as a result of ash deposition could have resulted in longer term changes to caribou ranges with caribou populations moving to areas with reliable resources.

Ethnographically, the mSRV was exploited during spring, summer, and fall (de Laguna and McClellan 1981; Osgood 1933, 1937; Townsend 1981); however, archaeological evidence suggests that upland areas including the mSRV were used during all seasons (Potter 2008c). Tephra deposition during the warmer seasons may have had a more direct and immediate impact on plant resources important to hunter-gatherers, and the effects of tephra deposition would have depended on the timing relative to the emergence of new shoots and leaves. The emergence of new shoots and leaves in spring typically occurs rapidly in interior Alaska, and has been recorded around June 1 in the nearby Little Susitna River Valley (Hock and Cottini 1966). If new shoots had already emerged from the ground, they would have been elevated above the tephra surface and therefore less inhibited by tephra deposition; however, tephra deposition prior to the emergence of new shoots would have inhibited growth of less woody species, which would have been unable to penetrate tephra (Antos and Zobel 2005). In spring, the potential for rain also could have resulted in the ash deposit hardening and forming a surface resistant to weathering and plant growth, but also resistant to erosion of tephra on slopes (Antos and Zobel 2005). If new leaves had emerged on deciduous species, ash fallout could have defoliated them, whereas if tephra deposition occurred prior to the emergence of new leaves, plants could have foliated relatively unaffected (Griggs 1915). Mosses and lichens would have been completely buried by tephra regardless of the timing of tephra deposition of spring, and would have been incapable of growing through the deposit (Antos and Zobel 2005).

The timing of tephra deposition in spring in the mSRV would have greatly affected how detrimental ash deposition was to animals using the area, which in spring and summer includes bears, marmot, wolves, squirrels, hares, fox, moose, sheep, and caribou. If stems were able to penetrate the ash, and leaves able to sprout, effects may have been less detrimental for species relying on green plant matter, and may not have extended beyond inhalation and ingestion of ash, but could have also resulted in ingestion of acids that can cause death (Cronin et al. 1998). As calving season for sheep, caribou, and moose, juveniles and pregnant individuals would have been at a greater risk for mortality related to ash ingestion (Cronin et al. 2003; Rubin et al. 1994).

Tephra deposition after the emergence of shoots and leaves, in late spring and during summer, would have also had the great impact on the flora and fauna in the mSRV, as the area was most populated by animals during this productive period. Tephra deposition during summer could have defoliated some species and buried others (Antos and Zobel 1982); this could have resulted in scarcity for animal species relying on leafy parts of plant species, which in summer include moose, sheep, caribou, bears, marmot, wolves, squirrels, hares, and fox, as well as ingestion of tephra (Alaska Department of Fish and Game 2015). Tephra deposition in the absence of snow to cover it would have increased likelihood of tephra being re-suspended in the air following deposition (Antos and Zobel 1982; Griggs 1915; Kellerer-Pirklbauer et al. 2007), causing further complications for animals in the area.

During fall, many animal species abandon upland areas prior to winter whereas others require large amounts of resources as they prepare for the rutting season (Alaska Department of Fish and Game 2015). The transition from fall to winter often involves alternating conditions of rain and snow; if rain had occurred following tephra deposition, the tephra deposit could have become somewhat cemented prior to snow fall, complicating plant growth the spring following tephra deposition. Rain, however, could have also contributed to weathering and erosion of the deposit on slopes, which would have eased plant growth in those locations the subsequent spring

(Griggs 1918). Likewise, snowfall on tephra that had been deposited in early fall in the mSRV could have facilitated erosion of the deposit, as the first snowfalls often melt. Contrarily, if the tephra and snowfall occurred later in fall, and snow did not melt prior to the onset of winter, the tephra deposit would have been better preserved and potentially compacted, making spring plant growth more difficult.

5.2.4 Immediate effects of ash deposition on humans

The effect of ashfall on humans depends on their proximity to the source of the ash and ability for protection. Because the mSRV is distal to Hayes Volcano and other Alaskan volcanoes that could be the source of the Oshetna tephra, tephra would not have been hot when falling; however, as the Novarupta-Katmai eruption of 1912 eruption demonstrated, respiratory distress and eye complications can occur in populations in distal locations as a result of ashfall. The habitants of Kodiak Island, over 170 km from Novarupta vent, experienced both (Hildreth and Fierstein 2012).

Evidence for residential structures has been reported in Alaska as early as the late Pleistocene (Potter et al. 2011). While temporary structures could have offered protection from ashfall, it is likely that if prehistoric peoples were in the mSRV at the time of ash deposition they would have experienced both respiratory distress and eye complications. Given the highly mobile nature of prehistoric hunter-gatherers in interior Alaska during the Holocene, it is also possible that populations could have re-located to areas less affected by ashfall depending on the responses of animal resources. Ash could have been re-suspended for years following initial deposition in the mSRV and could have caused continual temporary discomfort when people were in the area.

5.2.5 Tephra deposit thicknesses in the mSRV

The qualitative model above has used general concepts derived from historic volcanic events as a means to understand how tephra deposition in the mSRV could have impacted plants, animals, and people. Tephra deposits in the mSRV vary in thickness and preservation on the landscape, which suggests that ecological responses to the deposition of these tephra in the mSRV varied as well and contributed to a heterogeneous landscape. Notably, the Oshetna and Devil tephras, with deposit thicknesses that range from 3–5 cm thick, could have impacted bryophytes. However, it is less likely that these events had an effect on herbs and shrubs, as studies on Mount St. Helens have demonstrated that most herbs are able to survive a tephra deposit of 4.5 cm without snow cover (Antos and Zobel 2005). Contrarily, if snow were on the ground during these eruptions, the impact to herbs and shrubs potentially could have been more detrimental to vegetation, while also potentially offering uncontaminated sustenance for small mammals in the area (Antos and Zobel 2005; VanderHoek and Nelson 2009).

The lower unoxidized Watana and upper oxidized Watana tephra deposits, however, each have maximum thicknesses of 10 cm and it is unclear if these events were deposited simultaneously or separated in time. If the two tephras were deposited simultaneously, the resulting deposit—with a maximum thickness of 20 cm—would have negatively impacted bryophytes, herbs, and shrubs, and would have entailed a much longer vegetation response time. If the two events were separated in time by a few hundred years (Section 4.2.2.2), though, each could have negatively impacted bryophytes and some shrubs, with a less extensively time for vegetation recovery after each event. Bryophytes, including lichen, would have been particularly sensitive to all tephra depositional events in the mSRV and could have taken 20–80 years to recover (Collins et al. 2011; Henry and Gunn 1991). In addition, the oxidized Watana tephra has been noted to appear as a durable, cemented layer (Dilley 1988) and it is unclear if this occurred directly after deposition, in which case it may have impacted soil water and nutrient access. In relation to soils, spodosols (soils with accumulated aluminum and iron oxides), which often develop from tephra deposits, are being noted as pervasive in the mSRV (Dilley 1988).

5.3 Summary

Evidence of tephra deposits in archaeological contexts is not evidence that the volcanic events caused change in the environment or in hunter-gatherer behavior. The scale, magnitude, and nature of both volcanic and cultural deposits need to first be evaluated relative to the environmental context in order to reconstruct and understand the processes and mechanisms by which volcanic eruptions could have affected people in an area (Shimoyama 2002; Torrence 2002). This chapter has provided information on volcanic events and their effects in an effort to understand the potential effects of tephra deposition in the mSRV. Tephra deposit thickness and evidence of how plant species are affected by tephra deposition in other areas has been used qualitatively model how tephra deposition would have impacted vegetation and animals in the mSRV. In conjunction with the refined understanding of tephra deposits and their timing, and the timing and nature of the archaeological record in the mSRV (Chapter 4), this qualitative model may contribute to an understanding of how tephra deposition in the mSRV may have affected hunter-gatherer use of the area through time. These results are discussed and integrated in Chapter 6.

Chapter 6: Discussion

The stratigraphy of the mSRV includes periodic deposition of volcanic ash (Romick and Thorson 1983), which likely impacted plant and animal resources important to prehistoric hunter-gatherers who utilized the area. The general objective of this project was to clarify the stratigraphy of the mSRV and to investigate how the deposition of volcanic ash in the mSRV may have affected prehistoric hunter-gatherer land use in the mSRV. Addressing this objective required clarification of the mSRV stratigraphy and associated dates in order to provide an appropriate context for interpretation of the timing and nature of the archaeological record. In addition, the potential effects of ash deposition were modelled using information from historic volcanic events as a means to consider how ashfall may have impacted hunter-gatherer subsistence resources in the mSRV. This chapter is separated into two sections reflecting these differences in goals: Section 6.1 presents a discussion and summary of the refined mSRV stratigraphy, providing context for Section 6.2, which considers the archaeology of the mSRV in reference to the current understanding of interior Alaskan hunter-gatherer settlement and subsistence systems, and relative to the paleoenvironment and qualitative model for understanding the effects of tephra deposition in the mSRV.

6.1 Clarifying the stratigraphic contexts of the mSRV

Given issues with correlating and dating the mSRV tephra deposits in previous studies, the primary goals of this part of the study are to: 1) investigate the number of volcanic events represented in the stratigraphic record of the mSRV, 2) understand the relationship of mSRV tephras to Hayes Volcano, and, 3) establish a robust chronology of the mSRV tephra using existing and new radiocarbon dates. This aspect of the project was necessary to clarify the stratigraphy of the area and allow for more comprehensive evaluation of the archaeological record. This section is separated into two subsections: Subsection 6.1.1 summarizes the results of mSRV geochemical characterization and correlation; and, Subsection 6.1.2 summarizes the results of revised chronology for the mSRV.

6.1.1 Geochemical characterization and correlation of mSRV tephra

Figure 6.1 summarizes tephra characterization and correlation efforts of this study. Glass geochemical analyses indicate that the Oshetna tephra is heterogeneous with at least four populations of volcanic glass. Previous analyses of the Oshetna tephra, however, have only identified two population of volcanic glass in the deposit (Child et al. 1998; Dilley 1988) (Tables 2.1 and 2.2). Because the source, or sources, of the volcanic glass shards comprising the Oshetna tephra are unknown, it is difficult to evaluate its deposit in terms of the number of volcanic events represented. The Oshetna could be a product of Hayes Volcano, based on the proximity and thickness of the deposit; however, the deposit lacks biotite (Romick and Thorson 1983), which is a mineral characteristic to Hayes Volcano. Therefore, another possibility is that the deposit is reworked and representative of multiple tephra depositional events from different volcanoes. Ashfalls from nearby Cook Inlet volcanoes as recorded in lacustrine cores (de Fontaine et al. 2007; Schiff et al. 2008) suggest that numerous tephra deposits could be present in the mSRV. Redoubt, Augustine, Iliamna, and Spurr volcanoes could have deposited Holocene aged tephra in the mSRV and future correlation efforts will aid in understanding the Oshetna deposit.

Stratigraphically, the Watana tephra is separated into an upper and lower component, and there has been some question as to whether the deposit represents a single or multiple volcanic events (Dixon et al. 1985). Glass geochemical analyses demonstrate that the deposit is relatively homogenous despite differences in oxidation and color. Similarity coefficients calculated between mSRV Watana reference tephra samples and proximal Hayes Volcano reference samples suggest that the Watana tephra is correlative with the Hayes tephra set; however, most archaeological samples were taken as bulk Watana tephra samples, rather than as separate samples from the oxidized upper and unoxidized lower components of the tephra, which complicates correlation efforts. Specifically, Watana tephra samples correlate, with similarity coefficients greater than 0.95, to Hayes River Outcrop tephras D, E, F2, H (H1 and H2) of Wallace et al. (2014). Proximal tephras F and H represent eruptions large enough to have been deposited distally; the two samples of unoxidized portion of the Watana tephra have high similarity coefficients with proximal tephra F2, which is also unoxidized, whereas the two samples of the upper oxidized portion of the Watana tephra have high similarity coefficients with proximal tephra H, which is also oxidized.

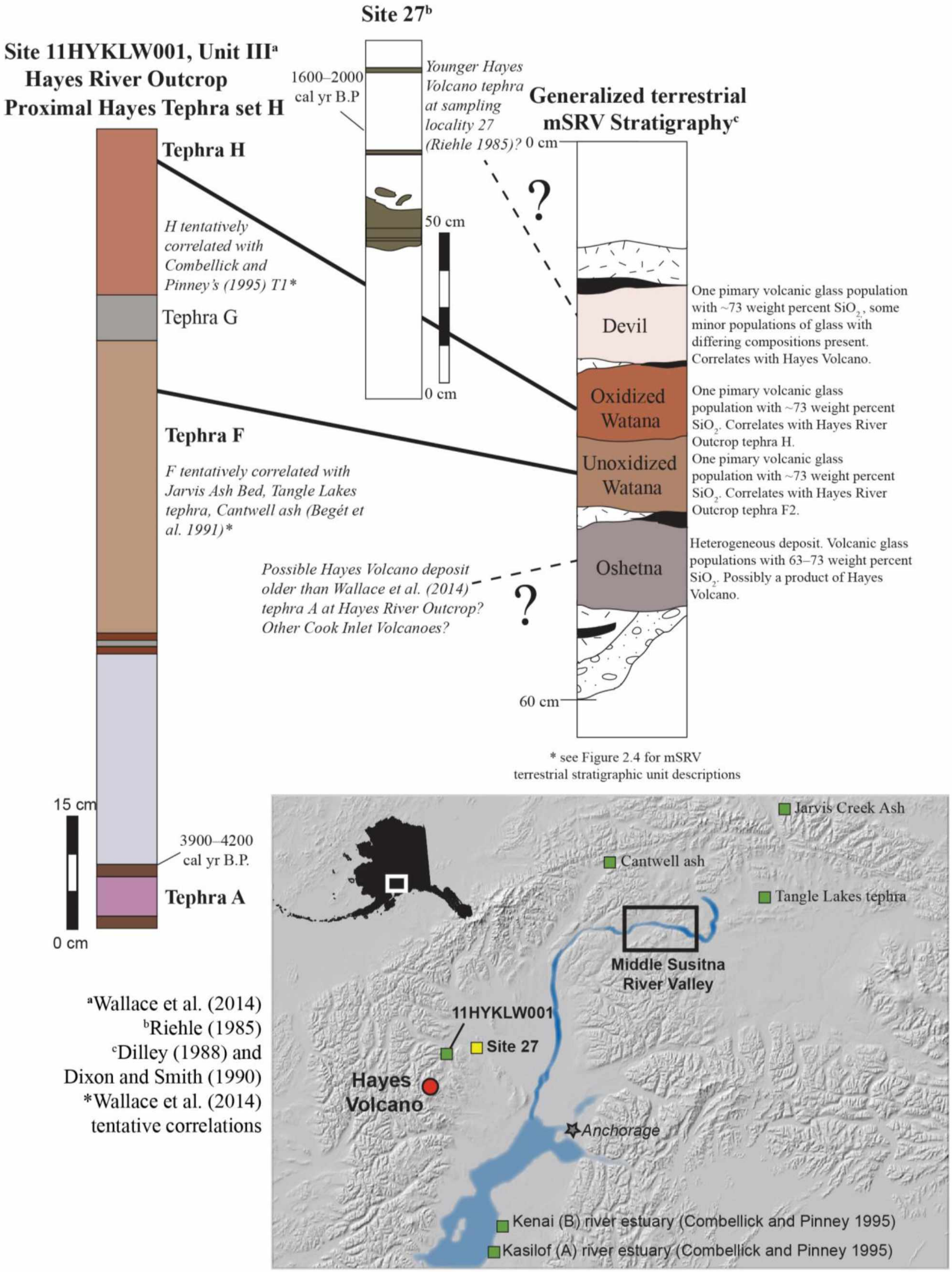


Figure 6.1. Summary of tephra characterization and correlation efforts in this study. See Table 3.4, Figure 2.6.

These results suggest that the Watana oxidized/unoxidized tephra couplet represents proximal tephras F and H of Wallace et al. (2014) (Figure 6.1). Proximal tephra F2 is unoxidized and is represented as the unoxidized portion of the Watana tephra in the mSRV, whereas oxidized proximal tephra H is represented as the upper oxidized portion of the Watana tephra in the mSRV. Indeed, archaeological investigations have occasionally noted eolian units or thin paleosols between the upper and lower portions of the Watana tephra, suggesting the deposit represents two volcanic events separated in time (Dixon et al. 1985; Romick and Thorson 1983). Schiff et al. (2008) also note two tephra beds in Bear Lake, south of Hayes Volcano, likely originating from Hayes Volcano (based on the presence of biotite), separated by 1.5 cm of gyttja and with a modelled basal age of 3940–4120 cal yr B.P. Bayesian models of calibration produced as part of this study suggest that deposition of proximal tephra F/unoxidized Watana and proximal tephra H/oxidized Watana could have occurred in rapid succession or been separated by a maximum of 380 years.

High geochemical similarity and the generally homogenous glass composition among samples of the Devil tephra within the mSRV suggest that it represents a single eruptive event. High similarity between the Devil tephra and proximal Hayes Volcano reference tephra suggest that the Devil tephra is a product of Hayes Volcano and perhaps even the Hayes tephra set H. Riehle (1985) reports on a Hayes Volcano sourced tephra layer dating younger than 1605–1990 cal yrs B.P. at sampling site 27, which coincides with the range of dates that bound the Devil tephra in the mSRV (Figure 6.1). Riehle (1985), however, does not provide a physical or chemical description of this young tephra, making a correlation only tentative. Future tephra sampling near Hayes Volcano may clarify the origin and distribution of the Devil tephra as well as improve the current knowledge of the timing of hazards posed by Hayes Volcano.

6.1.2 Revised dating of mSRV tephra

Recently obtained dates bounding mSRV differ from those produced in the 1980s bounding mSRV tephra (Figure 6.2). Dates on the deposition of the Devil tephra are only slightly older than the mSRV chronology developed in the 1980s; however, the recently obtained dates bounding the Watana and Oshetna tephras are significantly different from those obtained in the 1980s. One of the issues in correlating mSRV terrestrial tephra with mSRV lacustrine tephra

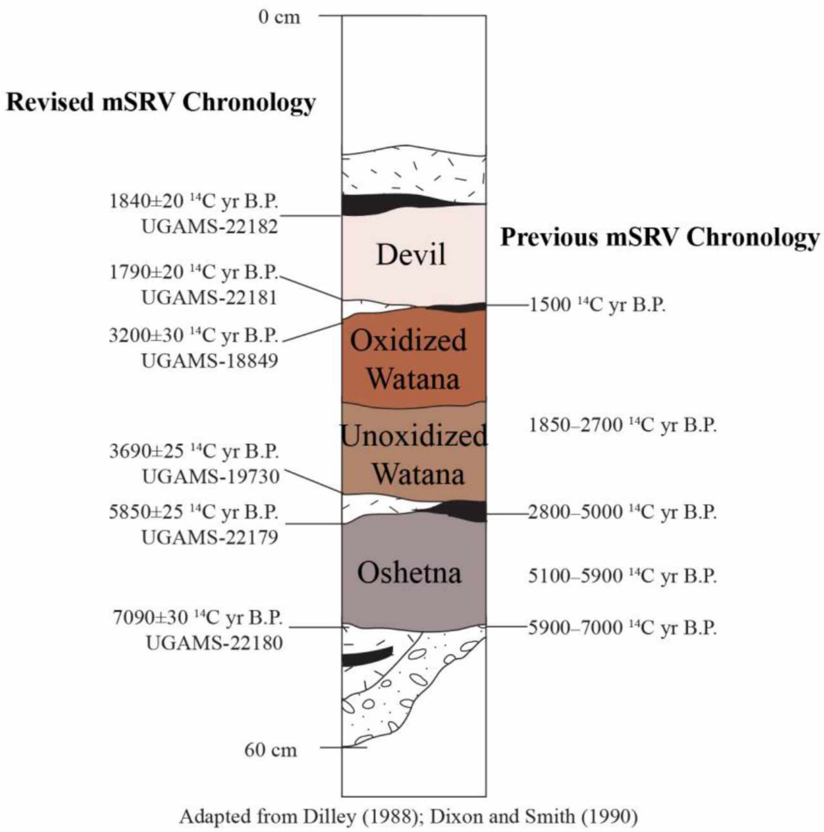


Figure 6.2. Revised mSRV chronology, compared to chronology established in the 1980s. Calibrated age ranges to 2 δ, with raw radiocarbon date ranges provided in parentheses. See Table 3.4 and 4.12 for radiocarbon sample information.

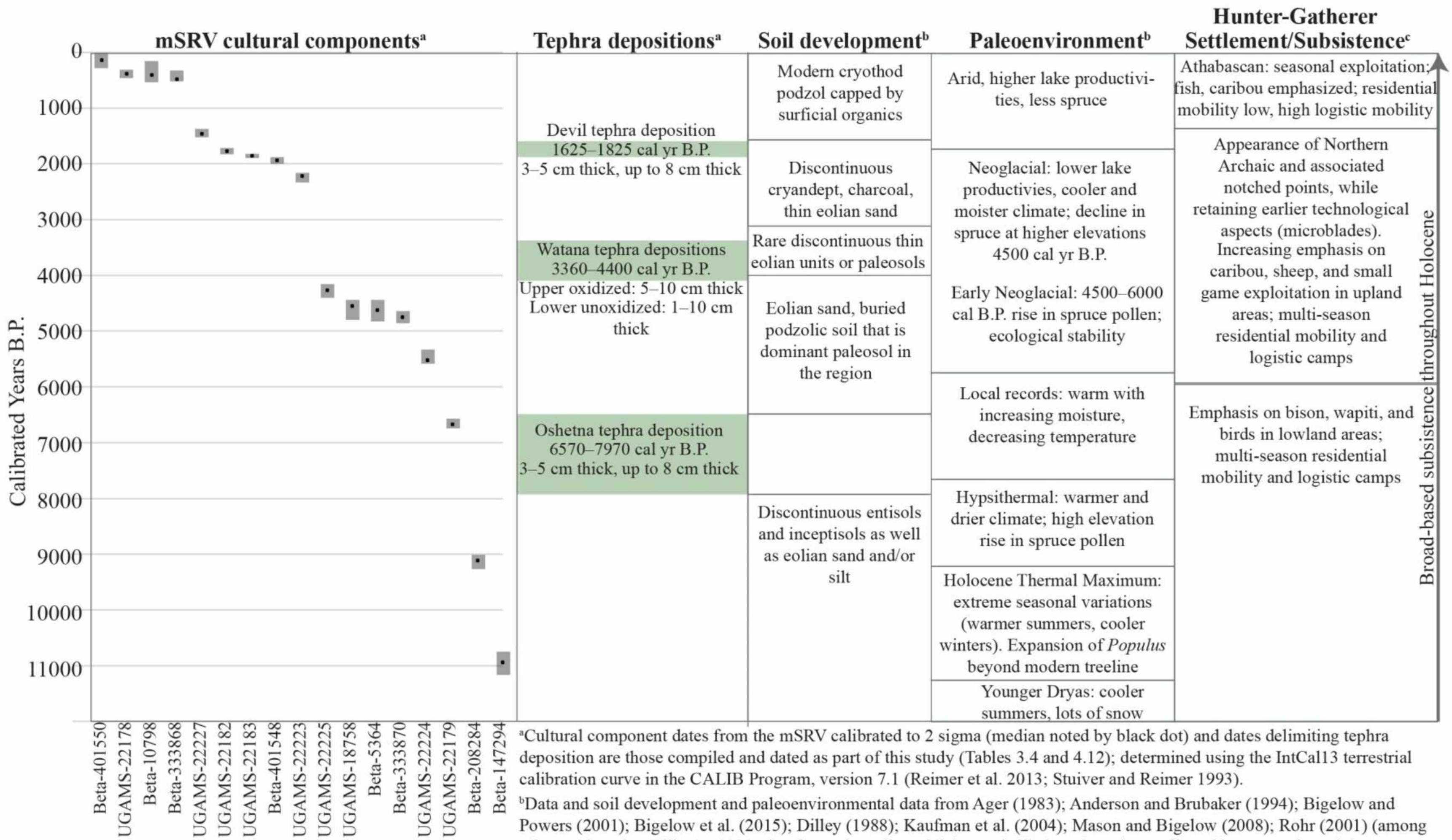
during the 1980s (Section 2.2.2) was the variability in dates associated with the deposits in different environments (terrestrial vs lacustrine) (Dilley 1988; Dixon and Smith 1990). Likewise, basal dates associated with the Hayes tephra set H in the proximal environment (Riehle 1985) were older than terrestrial dates associated with the Watana tephra in the mSRV (Dixon et al. 1985). The newly obtained dates delimiting mSRV tephra deposition address the problems associated with the 1980s terrestrial dates bounding mSRV tephra. Dilley (1988) proposed that the dates produced in the 1980s from lacustrine cores could have been too old as a result of coal contamination, or that the terrestrial dates produced during the 1980s could also have been too young as a result of contamination by downward leaching of more recent organics. The laboratories producing mSRV dates during the 1980s also could have contributed to dating issues in both the terrestrial and lacustrine environments (Reuther 2003; Reuther and Gerlach 2005).

Recently obtained dates from the mSRV presented here support Dilley's (1988) second hypothesis—that mSRV terrestrial dates produced in the 1980s are erroneously too young. However, it is not clear at this time whether this was a result of downward leaching of more recent carbon. It is clear, however, that the recently produced mSRV terrestrial dates suggest that tephras are older than previously thought. Delimiting the age of the Devil tephra is complicated by numerous stratigraphic ^{14}C reversals, but it is likely the tephra was deposited between 1625–1825 cal yr B.P. (~1800 ^{14}C yr B.P.). Recent dates indicate that the Watana tephra (both upper oxidized and lower unoxidized) were deposited between ~3360–4400 cal yr B.P. (between 3200±30 ^{14}C yr B.P. and 3690±25 ^{14}C yr B.P.), whereas 1980s dates suggested Watana tephra deposition between 1800–2900 cal yr B.P. (1850–2700 ^{14}C yr B.P.). The revised Watana dates make sense considering the recent basal ages of ~3900–4200 cal yr B.P. (3690±30 and 3750±30 ^{14}C yr B.P.) associated with the Hayes tephra set H at the Hayes River Outcrop (of Wallace et al. 2014). Dates bounding the Oshetna tephra in the 1980s suggested that it was deposited between ~5900–6700 cal yr B.P. (5100–5900 ^{14}C yr B.P.); however, this study indicates that the Oshetna tephra was deposited between ~6560–7970 cal yr B.P. (5850±25 ^{14}C and 7090±30 ^{14}C yr B.P. yr).

6.2 Archaeological contexts of tephra depositions in the mSRV and their effects

With a revised understanding of the tephra deposits in the mSRV stratigraphy and their timing, the second part of this study considers how the deposition of tephra in the area may have impacted prehistoric people. The timing of cultural occupations in the mSRV was evaluated relative to the timing of ashfalls, and potential periods of abandonment are indicated. The results of this research indicate that while ash deposition may have affected subsistence resources in the mSRV in the short term, the archaeological record of the mSRV is in agreement with broad changes in technology, settlement, and subsistence patterns through time throughout central interior Alaskan archaeology, suggesting that the deposition of ash did not contribute to these transitions.

Figure 6.3 provides the basis for the following discussion, which integrates dates on cultural components relative to the timing of volcanic events in the stratigraphy of the mSRV, as well our understanding of environmental and archaeological setting at the time. Recent research has refined our understanding of the climatic record of the marginal environment of the mSRV, demonstrating fluctuations throughout the Holocene (Bigelow et al. 2015; Rohr 2001). This allows for the timing and setting of cultural components in the mSRV to be considered relative to



[a]Cultural component dates from the mSRV calibrated to 2 sigma (median noted by black dot) and dates delimiting tephra deposition are those compiled and dated as part of this study (Tables 3.4 and 4.12); determined using the IntCal13 terrestrial calibration curve in the CALIB Program, version 7.1 (Reimer et al. 2013; Stuiver and Reimer 1993).

[b]Data and soil development and paleoenvironmental data from Ager (1983); Anderson and Brubaker (1994); Bigelow and Powers (2001); Bigelow et al. (2015); Dilley (1988); Kaufman et al. (2004); Mason and Bigelow (2008); Rohr (2001) (among others). Note that Dilley's (1988) timeframe for soil establishment is likely to have been affected by contaminated dates; therefore soil development is inferred from stratigraphic position relative to tephra deposits.

[c]Hunter-gatherer settlement/subsistence transitions from Anderson (1968); Dixon (1985); Esdale (2008); Potter (2008a, 2008b, 2008c); Shinkwin (1979).

Figure 6.3. Chronology of the mSRV synthesizing mSRV archaeological component dates, paleoenvironmental and archaeological data.

these datasets critically. In addition, potential hiatuses in cultural occupations, indicated by cultural radiocarbon dates, are considered relative to established transitions in hunter-gatherer settlement and subsistence systems through time in interior Alaskan archaeology. HBE dictates that hunter-gatherer populations are constrained by the resources available in the environment and their predictability, which affects methods of resource procurement and mobility patterns (Kelly 1983; Winterhalder 2001). Indeed, different settlement and subsistence strategies in the archaeological record of interior Alaska suggest that hunter-gatherers may have been affected by ash deposition in the mSRV differently through time and therefore this discussion is divided into three subsections that consider the paleoenvironmental and archaeological setting of the Oshetna tephra, Watana tephras, and Devil tephra separately.

6.2.1 Oshetna tephra: Context, deposition and effects

Early to mid-Holocene archaeological data in interior Alaska suggests that hunter-gatherers had a multi-season residential mobility pattern and incorporated a broad-spectrum diet (Potter 2008b, 2008c), with exploitation of large game such as bison and wapiti in lowland areas likely affecting the seasonal movement of hunter-gatherer populations (Glassburn 2015). The early Holocene in interior Alaska is a period of many environmental transitions as a result of de-glaciation and changes in climate and vegetation (Ager 1983). During the Holocene Thermal Maximum, from approximately 11,500–9000 cal yr B.P., conditions were warmer than present (Kaufman et al. 2004). Population size during the late Pleistocene to early Holocene was likely variable (based on component abundance as a proxy for population), with significant population decreases likely from 10,000–9000 and 8000–7000 cal yr B.P. (Potter 2008a, 2008b) and the Oshetna tephra deposition occurring shortly thereafter.

Despite these changes in environment and fluctuations in early Holocene populations, hunter-gatherers maintained and conserved their technologies and subsistence economies (Potter 2008b). Microblades, as part of a larger technological system (West 1975) are ubiquitous. Population fluctuations suggest that hunter-gatherers prior to and during the timeframe that the Oshetna tephra was deposited were sensitive to changes in climate and the environment (Potter 2008b) and therefore could have been negatively affected by Oshetna ashfall. Lithic assemblages below the Oshetna tephra in the mSRV contain microblades, which have been found to be differentially associated with large mammals such as bison and wapiti (Potter 2008a). Evidence of medium to large mammal fauna and identified caribou remains also indicate these resources were being obtained in the mSRV prior to deposition of the Oshetna tephra. No notched points are present in archaeological assemblages below the Oshetna tephra, which is to be expected given their association with archaeological components occurring after 6000 cal yr B.P. (Esdale 2008; Potter 2008a).

Prior to the Oshetna tephra deposition, there are only eight cultural components reliably located below the tephra during a period of ~4200 years. Notably, no cultural occupations in the mSRV date to during the Hypsithermal, during which the climate was warmer and drier (Ager 1983) and during which population in interior Alaska likely decreased in the timeframe of 8000–7000 cal yr B.P. (Potter 2008c). The Oshetna tephra was deposited during the period of the Hypsithermal in which temperatures were decreasing coincident with increases in moisture in the mSRV (Bigelow et al. 2015; Rohr 2001). Given the early to mid-Holocene demonstrated emphasis on bison and wapiti exploitation in lowlands (Potter 2008a), the scarcity of sites located stratigraphically below the Oshetna tephra, and the lack of dated archaeological components from 9000–6500 cal yr B.P., it appears that the mSRV (an upland area) was not used intensely prior to the deposition of the Oshetna tephra, especially compared to later periods of use of the area.

This study demonstrates that the 3–8 cm thick Oshetna tephra deposit, previously reported as having two geochemical populations of volcanic glass (Child et al. 1998; Dilley 1988), actually contains at least four populations of volcanic glass and was deposited between 6570–7970 cal yr B.P. Because the source (or sources) of the volcanic glass are not yet known, it is difficult to evaluate the deposit without a reference to proximal deposits to garner information on eruptive volumes and distributions. The fact that there are four populations of volcanic glass could be indicative of multiple smaller ashfall events being re-worked in the distal environment of the mSRV and being represented as a single unit, or could be the result of one larger eruption of a volcano with a heterogeneous magma chamber, resulting in populations of volcanic glass with different compositions (e.g. as with the Novarupta-Katmai eruption of 1912, Hildreth and Fierstein 2012). Multiple smaller eruptions would have individually deposited smaller volumes of tephra, potentially during different seasons, and deposits less than 2 cm may not have affected plant populations (Antos and Zobel 2005). Seven archaeological components occur within the Oshetna tephra, which could suggest that the unit is an amalgamation of events over time.

Alternatively, these components could be also be distributed throughout the Oshetna tephra because they occurred after its deposition and became mixed with the deposit as a result of disturbance from activities occurring on the tephra surface.

Because little is known about the sources and extent of the volcanic glass comprising the Oshetna tephra in the mSRV, and the wide age range associated with the deposit, it is difficult to postulate what the effects of tephra deposition were on the environment. The earliest dated component after the deposition of the Oshetna is the one that used to delimit the minimum age Oshetna tephra deposition, 6570–6740 cal yr B.P. (UGAMS-22179), at Jay Creek Mineral Lick site (TLM-143) (Tables 3.3 and 4.12). This occupation, which contains caribou remains, represents the second largest assemblage of both lithic and faunal remains recovered from the mSRV, including more than 31,000 bones, greater than 26,000 lithic materials, and seven classes of lithic artifact types (Dixon et al. 1985). The large artifact density and richness of the post-Oshetna occupation at the Jay Creek Mineral Lick (TLM-143) resembles others below the Oshetna tephra, possibly indicating similar settlement and subsistence strategies, specifically residential settlement and mobility characteristic of the early to mid-Holocene occupations (Potter 2008b). The component had been previously dated, as 1400 years younger (Dixon et al. 1985) than the new date and this single new date is difficult to evaluate, especially given the lack of dated sites with cultural components in the mSRV for approximately the following one thousand years, until an archaeological component that dates to between 5330–5583 cal yr B.P. at the Borrow C site (TLM-097) (UGAMS-22224).

Potter (1997) notes a hiatus in radiocarbon dates coinciding with cultural occupation of interior Alaska in general from 5500–6500 cal yr B.P., however, more recent radiocarbon analyses indicate consistent population increase after 6000 cal yr B.P. (based on component abundance as a proxy for population), and an earlier hiatus in upland components, from 6200–7700 cal yr B.P. (Potter 2008b). The hiatus in radiocarbon dates from cultural components in the mSRV, from ~5520–6670 cal yr B.P., could be related to changing land use and resource acquisition strategies among prehistoric populations in interior Alaska at that time, as well as emerging new technologies (Northern Archaic notched points) (Potter 2008b). Indeed, from 5000–8000 cal yr B.P., bison and wapiti, which dominate late Pleistocene and early Holocene archaeological assemblages, decrease coincident with increases in caribou exploitation (Potter 2011). The hiatus in the mSRV specifically could be related to the pattern of hiatuses in uplands, and may have been compounded by the deposition of the Oshetna tephra. In addition, local lake records indicate that the hiatus following the Oshetna tephra deposition occurs during a transition in the climate, with the warm and dry Hypsithermal becoming increasingly moist with decreasing temperatures towards the Neoglacial (Bigelow et al. 2015).

The archaeological component at Jay Creek Mineral Lick (TLM-143) could indicate that deposition of the tephra comprising the Oshetna tephra unit did not affect the environment severely or that the environment was able to recover by that time; indeed, for hunter-gatherers to return to the area, resources in the mSRV must have been in abundances great enough to attract hunter-gatherers to the area, or depleted below the mSRV levels in other areas (Kelly 1983). Because hunter-gatherers during the timeframe of Oshetna ash deposition were highly mobile and incorporated a broad-spectrum diet (Potter 2008b, 2008c), their mobility could have mitigated risk of resource scarcity (Kelly 2013). High residential mobility and broad-based subsistence would have enabled hunter-gatherer populations some flexibility to changes in resource availability and abundance at specific locations, allowing relocation to more resource rich patches and/or incorporation of resources abundant in those patches (Bettinger 1991; Binford 1980). While the effects of Oshetna ash deposition are difficult to model because the deposit is not well understood, if its deposition did affect resources in the mSRV, hunter-gatherer populations in interior Alaska at the time of Oshetna ash deposition could have been suited to cope with any effects of ash deposition due to the lack of evidence of extensive use of the mSRV and other uplands, the high degree of residential mobility that would have enabled relocation to other resource-rich areas, and also a broad-spectrum diet that may have allowed for dietary flexibility.

6.2.2 Watana tephra: Context, depositions, and effects

Although only five components are reliably dated between the Oshetna and two Watana tephras in the mSRV, four of them occur after 6000 cal yr B.P. and the appearance of Northern Archaic in interior Alaska (Andersen 1968, 2008). A total of 22 archaeological components are located stratigraphically between the Oshetna and Watana tephras, however, over a period of ~2810–2430 years. This gives a higher occupational intensity (one cultural occupation occurring every 118 years on average) of the mSRV than prior to Oshetna tephra deposition. In addition, the dominant paleosol in the region occurs between the Oshetna and Watana tephras, and could indicate relative ecological stability (Bigelow et al. 2015; Dilley 1988). While more frequent use of the area following Oshetna tephra deposition is indicated, it is likely that much of this occupational intensity is even higher and associated with the period after 6000 cal yr B.P., following the appearance of the Northern Archaic and more frequent exploitation of uplands and resources available there (Ackerman 2004; Esdale 2008; Mason and Bigelow 2008; Potter 2008b). Indeed, 23 percent of the 22 archaeological components between the Oshetna and Watana tephras in the mSRV have faunal remains of medium to large mammals, and 14 percent specifically have remains of caribou, indicating the resource was being exploited (Table 4.15). Similar to early Holocene settlement and subsistence patterns, Northern Archaic patterns exhibit high residential mobility and broad based subsistence (Potter 2008b). Northern Archaic components have been found associated with cool and moist climates (Mason and Bigelow 2008), and it was during the Neoglacial that the lower unoxidized Watana and upper oxidized Watana tephras, both part of the Hayes tephra set H, are deposited, between 3360–4140 cal yr B.P.

Taking into consideration stratigraphic characteristics and geochemical analysis, correlation of the Watana tephras as part of this project indicates that the Watana tephra, which stratigraphically appears as two distinct layers that differ in color and which had been previously treated as one deposit, could represent two volcanic events from Hayes Volcano. The lower unoxidized Watana ranges in thickness from 1–10 cm and the upper oxidized Watana from 5–10 cm (Romick and Thorson 1983). Because the lower unoxidized and upper oxidized Watana tephras represent ashfall events that could have occurred in rapid succession or could have been separated by a few hundreds of years, deposition of these tephras likely affected the environment more profoundly than did deposition of the Oshetna tephra (which is thinner and could be a re-worked deposit of multiple smaller eruptions).

Other historic volcanic events were used to explain the potential effects of tephra deposition in the mSRV, and tephra deposits of greater than 4.5 cm are demonstrated to have an adverse impact on bryophytes (Antos and Zobel 2005; Griggs 1918). Specifically, lichen relied on by caribou in winter could have been buried by the deposition of the lower unoxidized Watana tephra, and could have caused migration of caribou from the mSRV to areas with greater amounts of lichen. Given the timeframe for lichen recovery, which could range from 20 to more than 80 years depending on if any viable lichen survived to aid in recovery (Collins et al. 2011;

Henry and Gunn 1991), caribou may or may not have returned to the mSRV by the time the 5–10 cm thick upper oxidized Watana tephra was deposited, which could have occurred immediately following the unoxidized Watana tephra, or a maximum of 380 years later. Caribou return to the mSRV would have been attractive only if lichen foraging was not optimal in other regions of interior Alaska (Collins et al. 2011). Alternatively, tephra deposition could have decimated caribou populations, especially if volcanic eruptions occurred in spring, during which juveniles and pregnant females are sensitive tephra toxicity (Cronin et al. 2003; Rubin et al. 1994). The eastern lobe of the White River Ash, deposited approximately ~1200 cal yr B.P. is thought to be a contributing factor to partial caribou population replacement in the Yukon (Kuhn et al. 2010), as well as hiatuses in cultural occupation of the area affected by ash deposition (Mullen 2012). Likewise, caribou populations on the Alaska Peninsula migrated and decreased in size following the 1825 and 1826 eruptions of Unimak Volcano (Trowbridge 1976; Veniaminov 1840; Workman 1979). If caribou populations were significantly affected by the depositions of the Watana tephras, Northern Archaic populations utilizing caribou resources in the mSRV uplands could have initially been at a disadvantage following deposition of the lower unoxidized Watana tephra.

Importantly, however, other small mammals were being obtained in upland locations during this period (Potter 2008c). The implications of tephra deposition on small mammals are less clear and likely depended on the seasonal timing of tephra deposition. Tephra deposition in spring prior to green-up may have been less detrimental than after foliation, which could have caused defoliation of plant species and resource shortages for small mammals (Crisafulli et al. 2005). In general, tephra deposition during spring would have been detrimental to juveniles and pregnant females, as tephra ingestion can cause death in these individuals (Cronin et al. 2003; Rubin et al. 1994). Although this is demonstrated for grazing animals, it is likely true of all animals relying on plant matter coated in tephra. Likewise, tephra deposition in winter may have decreased plant growth abilities the following spring, decreasing small mammal resource availability, or could have protected plants from tephra and provided uncontaminated plant resources for small mammals (Antos and Zobel 2005; VanderHoek and Nelson 2007). The implications of small mammal resource availability to hunter-gatherers are less clear as these faunal remains are less likely to be preserved in the mSRV thus are absent in most faunal assemblages from the area. After the Mount St. Helens eruption, Crisafulli et al. (2005) note that small mammals mostly survived and remained in areas of tephra deposition, disturbing the tephra deposit and accelerating biological recovery in the immediate vicinity. Therefore, if caribou were negatively affected by tephra deposition and were not readily available in the mSRV, small mammals may have been an important resource contributing to the generally broad-spectrum diet during this time frame.

This research presents a gap in radiocarbon dating of cultural occupations of the mSRV following deposition of the two Watana tephras, despite relative climatic continuity (Bigelow et al. 2015; Rohr 2001) and continuity in hunter-gatherer settlement and subsistence systems (Anderson 1968; Esdale 2008; Potter 2008c) (Figure 6.3). Although the gap, which begins at ~4270 cal yr B.P. (UGAMS-22225 cal. median at TLM-046) and extends to ~2225 cal yr B.P. (UGAMS-22223 cal. median at TLM-062), is likely the result of a biased data-set, it could also be indicative of the local area of the mSRV being abandoned in response to resource scarcity, which is predicted by optimal foraging theory and patch choice models (Bettinger 1991; Kelly 2013; Winterhalder 2001). Because Northern Archaic hunter-gatherers exploited caribou, lack of the higher-ranked caribou resources in the mSRV would have made it a less-attractive patch—despite lesser ranked small mammal availability—and optimal foraging theory dictates that hunter-gatherers may have relocated to more attractive patches (areas with more readily available resources) (Bettinger 1991). High residential mobility and broad-based subsistence of Northern Archaic populations likely mitigated this risk of resource scarcity in the mSRV, and Northern Archaic hunter-gatherers could have responded to tephra deposition by re-locating to more productive resource areas or incorporating a greater proportion of non-caribou resources and effectively widening their diet breadth. Potter (1997) previously noted a hiatus in the archaeological record of interior Alaska, ranging from 3000–4000 cal yr B.P., which has more recently been restricted to the Tangle Lakes area (Potter 2008a); however, this research suggests that the hiatus includes the mSRV, and is extended there.

Hunter-gatherer abandonment of the mSRV could have initially occurred as a result of Watana ash depositions and subsequent decreases in resource availability; however, Watana tephra depositions are followed by a period in which local paleoenvironmental records indicate lower lake productivities, a decline in spruce at higher elevations, a cooler and moister climate (Rohr 2001), and formation of only discontinuous paleosols on top of Watana tephra surfaces (Dilley 1988). While the Northern Archaic hunter-gatherer system has been associated with cooler and moister climates (Mason and Bigelow 2008), the timing of Watana ash deposition could have prolonged ecological recovery in the mSRV and contributed to an extended absence of prehistoric hunter-gatherers in the area. Indeed, the first dated cultural component following the deposition of the Watana tephras does not occur until 2160–2330 cal yr B.P., at the Red Scraper site (UGAMS-22223, at TLM-062). Although this component does not contain notched points characteristic of the Northern Archaic, it does contain faunal remains of medium to large mammals, including caribou, indicating these resources were again being exploited in the area. None of the cultural components stratigraphically between the Watana tephras and the Devil tephra, contain notched points; however, this analysis did not include cultural components that could not be reliably bracketed between the upper oxidized Watana tephra and overlying Devil tephra. This period does span a time during which existing archaeological frameworks establish the Northern Archaic in interior Alaska thus the absence of notched points between the Watana and Devil tephras reported here is likely not real. Therefore, the Northern Archaic systems using the mSRV prior to Watana tephra deposition appear to return and re-use the area following the hiatus potentially associated with Watana tephra deposition, demonstrating conservative resource acquisition strategies over thousands of years and despite different land use patterns.

6.2.3 Devil tephra: Context, deposition, and effect

The cool and moist climate of the Neoglacial persists following reoccupation of the mSRV after the Watana tephras are deposited (Bigelow et al. 2015; Rohr 2001). All four reliable cultural component dates that occur prior to Devil tephra occur within the timeframe during which Northern Archaic is established in interior Alaska and contain large mammal or caribou remains. Among the 19 cultural components located stratigraphically above the Watana tephras and below the Devil tephra, 47 percent have faunal remains of medium to large mammals (37 percent have caribou remains specifically) (Dixon et al. 1985) (see Table 4.15), indicating that caribou remained an important resource being exploited in the mSRV. Assuming that the cultural hiatus after the Watana tephra depositions is real, 19 cultural components occur within the period of ~270–590 years prior to the deposition of the Devil tephra, giving an occupational intensity during that period of one cultural component every 22.5 years, higher than any previous ash-bounded periods of occupation in the mSRV.

Deposition of the Devil tephra was likely between 1625–1825 cal yr B.P., and likely represents a single volcanic event, although it is not represented at the Hayes River Outcrop (of Wallace et al. 2014). The Devil tephra ranges from 3–5 cm thick where it is present, and therefore could have buried bryophytes to the point of sparse survival (Antos and Zobel 2005), which may have affected caribou distributions (Collins et al. 2011; Henry and Gunn 1991); however, Devil tephra deposition may have been even less detrimental to the environment, as herbs and shrubs could have recovered within a few years (Antos and Zobel 2005; Griggs 1915).

Deposition of the Devil tephra also occurs during the period that is archaeologically characterized by the Northern Archaic Tradition in interior Alaska, which could indicate that hunter-gatherers had a similar response to that of Watana tephra depositions. High residential mobility characteristic of Northern Archaic occupation of interior Alaska (Potter 2008c) would have facilitated increased mobility of hunter-gatherer groups in response to any negative effects caused by ash deposition (Binford 1980). Caribou in the mSRV appear to have been an important resource to Northern Archaic hunter-gatherers, and if Devil tephra deposition caused caribou to abandon the area due to lichen burial, then Northern Archaic hunter-gatherers may also have altered their mobility patterns to accommodate subsistence, which was broad-based (Potter 2008c).

The first dated evidence for cultural use of the mSRV following the Devil deposition is at TLM-216, which dates to 1380–1520 cal yr B.P. (UGAMS-22227). This date, however, is from a component that stratigraphically pre-dates the deposition of the Devil tephra, making the date suspect of contamination, or the tephra misidentified as the Devil tephra (no tephra samples were taken from this location, preventing geochemical analysis and correlation). Therefore, with the exclusion of this date, another potential hiatus occurs after the deposition of the Devil tephra in the mSRV. This hiatus in dated cultural occupations in the mSRV occurs from the time of Devil tephra deposition and extends to 385 cal yr B.P. (UGAMS-22178 cal. median at TLM-050). This is coincident with another climatic transition indicated in mSRV paleoenvironmental records, during which the moist and cool climate of the Neoglacial is replaced by that of the Medieval Optimum, a period from roughly 750–1400 cal yr B.P. during which the climate was more arid and lake productivities higher despite less spruce (Rohr 2001).

Potter (1997) also notes a hiatus in interior Alaska dated archaeological components, extending from 700–1000 cal yr B.P., and after which archaeological components characteristic of the Athabascan Tradition appear; however, more recent analyses have found no hiatuses or inferred population declines in the past 6000 cal yr B.P. (Potter 2008a). The presence of notched points in archaeological components located stratigraphically above the Devil tephra in the mSRV signifies that Northern Archaic populations returned to the area following Devil tephra deposition. This suggests that the post-Devil cultural hiatus in the mSRV may not be as extensive as indicated, because the hiatus currently extends through the significant shift in the archaeological record of interior Alaska, from the Northern Archaic to the Athabascan Tradition, which typically occurs approximately 1200 cal yr B.P.

The Athabascan Tradition is characterized by a reduction in lithic technology with increased evidence of organic technology and use of copper, as well as evidence of food storage and procurement of seasonally abundant resources; these changes are reflective of an increase in logistical mobility and decrease in residential mobility (Dixon 1985; Potter 2008c; Shinkwin 1977, 1979). Four of five dated cultural components from above the Devil tephra coincide with this period, and do characteristically display a decreased emphasis on lithic technology, while also containing caribou remains likely indicative of seasonal procurement of the resource. In addition, moose is noted above the Devil tephra. This is interesting given the absence of moose at other stratigraphic positions (Table 4.15), and the more likely potential for moose remains to be preserved (larger bones) if they were being obtained prior to Devil tephra deposition. Indeed, although moose are an emphasized resource in Athabascan ethnographic literature, there is debate regarding the antiquity of reliance on the resource (Yesner 1989). Archaeological evidence indicates caribou and other upland resources (including sheep, moose, bear, and ground squirrel) had a greater contribution to diet prior to 1300 cal yr B.P. (Reckord 1983; Simeone 2006; Yesner 1989). An increase in reliance on fish, possibly related to the diminished availability of bison as a resource, is also indicated during the Athabascan period (Potter 2008a). Forty cultural components are reliably located above the Devil tephra, indicating a slightly decreased occupational intensity compared to the previous period (one cultural component for every 45 years). Of the 40 cultural components located above the Devil tephra, 45% have preserved faunal remains of medium to large mammals and 33% of them have identified caribou elements; cultural depressions typical of habitation or storage features associated with the Athabascan Tradition are also observed above the Devil tephra (Dixon et al. 1985).

The cultural hiatus after the deposition of the Devil tephra is more difficult to evaluate because of the coincident change in climate during the Medieval Optimum (Rohr 2001) and the sampling bias indicated by the presence of notched points above the Devil tephra, but a lack of dated components older than 385 cal yr B.P. While deposition of the Devil tephra may have negatively affected the environment, leading to temporary abandonment of the area by Northern Archaic hunter-gatherers, the subsequent change in climate may have exacerbated resource scarcity and therefore extended abandonment of the mSRV until the appearance of the Athabascan Tradition in interior Alaska.

6.2 Evaluating responses to ashfalls in the mSRV

Historic volcanic events suggest that tephra deposition in the mSRV could have affected both plant and animal resources (Antos and Zobel 2005; Griggs 1915; Hildreth and Fierstein 2012; Swanson et al. 2005), potentially affecting hunter-gatherer strategies and use of the mSRV. This research demonstrates that archaeological assemblages in the mSRV do not indicate that deposition of tephra invoked significant changes in the archaeological record independent of transitions already indicated in the broader archaeological record of interior Alaska. Changes in the characteristics of archaeological assemblages in the mSRV coincide with the timings of transitions in archaeological assemblages in interior Alaska in general, and therefore likely occured independently of ash depositional events in the mSRV. However, ash deposition may have contributed to extended hiatuses in hunter-gatherer use of the mSRV, hiatuses which may also be indicated in other areas of interior Alaska and reflective of changing land use strategies or fluctuations in population (Potter 1997; Potter 2008b).

The Oshetna tephra could have impacted plant resource availability; however, the area was infrequently used and uplands were not emphasized during the timeframe of deposition, making the hiatus likely to be less related to deposition of the poorly understood Oshetna tephra (Table 6.1). In particular, the thickness of the upper oxidized and lower unoxidized Watana tephra deposits suggests that these events could have significantly impacted resource availability in the mSRV, thus contributing to a potential hiatus in cultural use of the area that occurs despite climatic continuity and continuity in hunter-gatherer settlement and subsistence systems. Interestingly, Northern Archaic systems using the mSRV prior to the Watana tephra depositions

Table 6.1. Effect of tephra deposition at different times in the mSRV.

mSRV tephra unit[a]	Deposition date[b]	Deposit thickness, cm	Potential effects on plants, resources[c]	Occupational intensity of the mSRV[d]	Date of earliest occupation after tephra deposition[e]	Response time[f]
Devil	1825–1625	3–5, up to 8	Negative effect on bryophytes in patches, some herbs	19 components between the Watana and Devil (1 component every 22.5 years)	310–462	? Notched points above Devil tephra, earlier re-occupation of the area than dates indicate
Oxidized Watana	4140–3360	5–10	Detrimental as independent events, very detrimental as two rapid succession events: bryophytes buried, herbs buried, shrubs partially buried. Caribou negatively impacted by lichen availability	22 components between Oshetna and Watana (1 component every 127 years)	2458–2332	>1000 years
Unoxidized Watana		1–10				
Oshetna	7970–6570	3–5, up to 8	One event: negative effect on bryophytes and some shrubs; multiple events: possible effect on bryophytes in patches	8 components below Oshetna (1 component every 525 years)	6570–6740	? Infrequent use of area

Relationship between tephra depositions, effects on resources, and effects on re-occupation of the area by hunter-gatherers. [a]Informal tephra unit names from the mSRV; [b]Calibrated age ranges for tephra deposition determined in this study; [c]Potential effects of tephra deposition on plants, outlined in Chapter 5; [d]Occupational intensity is determined by dividing the number of components located at each stratigraphic position by the amount of time between tephra units bounding that stratigraphic position; [e]Calibrated age range of earliest component dated after each ashfall event; [f]Response time for hunter-gatherers estimated.

appear to return to the area and use it in a similar way following the post-Watana hiatus. The Devil tephra, likewise occurs during Northern Archaic domination in central interior Alaskan archaeology, but is a thinner deposit thus likely had less of an impact.

Cashman and Giordano (2008:326) state that “From a societal perspective, it is clear that small mobile communities with strong connections to their neighbors can most easily adapt to the disruption caused by volcanic disasters…” Indeed, the hunter-gatherers in interior Alaska were likely affected by the impact that volcanic ash deposition had on resources; however, patterns of mobility and subsistence likely mitigated the negative consequences of ash deposition on resources in the mSRV. The archaeological record in the mSRV provides evidence that subsistence and settlement patterns persisted and were conserved before and after significant volcanic events that likely affected resource availability in the mSRV. Resilience in the face of these drastic events is more likely than the sometimes assumed local extinction or population replacement. The changes in the subsistence and settlement pattern in the archaeological record of interior Alaska at 6000 and 1200 cal yr B.P. were therefore related to events other than these volcanic ones preserved in the stratigraphy of the mSRV.

The question of what facilitated changes in settlement and technology patterns indicated in the archaeological record of interior Alaska is one that has been subject to debate, particularly as existing normative cultural historical frameworks are brought into question as archaeological analyses incorporate greater amounts and types of data. The appearance of the Northern Archaic Tradition in interior Alaska (~6000 cal yr. B.P.) and coinciding new technologies is difficult to evaluate given the inability to apply analogous ethnographic data from Athabascan groups, which have markedly different settlement and subsistence patterns. Indeed, as Esdale (2008) summarizes, more questions have arisen than have been answered regarding the Northern Archaic. However, studies such as Esdale (2008) and Potter (2008a, 2008b; 2011), which consider multiple datasets, will aid in answering these questions and explaining transitions in the archaeological record of interior Alaska.

Most recently, the transition to the Athabascan Tradition (Shinkwin 1977, 1979) exhibits even more conspicuous changes in land use and settlement patterns. Evidence suggests that protohistoric and historic Athabascans are linked to the archaeological Athabascan Tradition, with linguistic analyses suggesting that the Athabascan branch of the Na Dene language family occurred approximately 2000 years ago (Dumond 1969). While this allows for evaluation of the recent (post 1200 cal yr B.P.) archaeological record through the use of ethnographic analogy and knowledge of Athabascan lifeways the question of what facilitated the recent conspicuous transition in the archaeological record remains.

Potter (2008a) considers differing models that could account for such changes and finds that a transition in the technological and economic system is the most likely scenario. Indeed, ice patch archaeology provides evidence of the introduction of the bow and arrow around 1000 cal yr B.P. (Hare et al. 2004), which coincides with the disappearance of the microblade from the archaeological record of interior Alaska. Potter (2008a) further posits that the two co-occur when bison populations would have lowered below being a stable and dependable resource, possibly related to disappearing habitats and over-hunting following introduction of the bow and arrow (Stephenson et al. 2001). In the mSRV, this transition to cultural components characteristics of the Athabascan Tradition post-dates the deposition of the Devil tephra, suggesting that its deposition may not have affected the technological and economic system of the Athabascan Tradition. Local abandonment of the mSRV following Devil deposition is potentially indicated in this research, but is complicated by inadequate radiocarbon dating above the Devil tephra:

notched points are present above the Devil tephra, but the earliest dated component occurs after the transition to the Athabascan Tradition.

The question that remains in this research is why there are such significant hiatuses in the cultural occupation of the mSRV. The effects of historic volcanic events suggest ecological recovery should not have taken as long as the hiatuses extend, despite the mSRV being a marginal environment that likely took longer to recover than the environments of historic volcanic eruptions indicate. Recent Bayesian modeling of the Na-Dene languages suggest multiple waves of migration out of Beringia, with subsequent back-migration, explaining linguistic relationships between Na-Dene and Yeniseian languages (Sicoli and Holton 2014). This pattern is supported by recent analysis of mitochondrial DNA from the Americas and Asia, which also suggests migration out of Beringia following a period of time spent in Beringia, with subsequent back migration (Tamm et al. 2007). While these data predate the timeframe for this analysis, they do suggest that prehistoric populations of hunter-gatherers were highly mobile over multiple generational periods and could have used and abandoned areas over periods of thousands of years. The most likely explanation of the hiatuses indicated in this research, however, is inadequate sampling, which future archaeological work in the mSRV will aid in addressing. Indeed, despite the plethora of work that was done in the mSRV during the 1980s, our understanding of the prehistoric use of this area remains limited and recent archaeological surveys have continued to find archaeological sites in the mSRV. While this work will contribute to a greater understanding of this area, more syntheses considering multiple datasets are necessary. The number of cultural radiocarbon dates considered in this analysis (17 cultural component dates) is miniscule compared to the number of sites in the mSRV, which is over 285. As more modern radiocarbon dates from this area become available, these hiatuses will be evaluated, as will our understanding of how prehistoric hunter-gatherers responded to ashfall events in the mSRV.

6.3 Summary

This chapter has considered the archaeological record of the mSRV relative to the refined stratigraphic record of the area. This research indicates that the volcanic events in the mSRV may have affected the availability of resources in the mSRV and contributed to hiatuses in use of the area, most likely following the Watana tephra. However, it is likely that tephra deposition did not significantly contribute to transitions in the archaeological record of interior Alaska. Differences in mobility and subsistence economies of prehistoric hunter-gatherers at the times of different ash depositional events in the mSRV suggest that the effects of ash deposition on hunter-gatherers may have been different as a result of different resources being emphasized through time; however, caribou, specifically, would have been affected by ash deposition. Future research on tephra correlation, and the seasonal timing of tephra deposition in the mSRV will aid evaluating the effects of the events on people.

Chapter 7: Conclusion

This project has clarified the general Holocene stratigraphic sequence of the mSRV, provided additional evidence for at least four discrete ashfalls, revised the dates delimiting tephra deposition in the mSRV, refined the dating of archaeological components, and evaluated archaeological assemblages bounded by tephra events in the mSRV. However, there remain ambiguities in understanding the tephra deposits in the mSRV and how they affected the environment and people. These ambiguities can be addressed in future research, some suggestions of which are provided below (Section 7.1), followed by a general conclusion to this study (Section 7.2).

7.1 Future Directions of Research

This study has demonstrated that the mSRV Oshetna tephra is comprised of at least four populations of volcanic glass, none of which correlate to Hayes Volcano tephra at the Hayes River Outcrop (of Wallace et al. 2014). The Oshetna tephra could, however, be an older product of Hayes Volcano based on its geochemical similarity to other Hayes tephras. Future investigations may consider other Alaskan volcanoes that have records of eruptive phases within the refined age estimate of the Oshetna tephra presented in this study. In addition, future investigations of the Oshetna tephra may reveal if different populations of volcanic glass are present in different areas of Alaska, providing information on the distribution and timing individual volcanic events if in fact this tephra is comprised of multiple discrete units. For example, Child et al. (1998) present two populations of volcanic glass in Oshetna tephra samples from Wonder Lake cores, which may indicate specific volcanic plume directions and areas of deposition.

Additional tephra analyses in the Cook Inlet area may reveal more information about individual tephra layer distributions from the Hayes tephra set H and their timing, and other potential tephra layers originating from Hayes Volcano. Although the Watana tephra is demonstrated to represent two Hayes volcanic events, the timing of these events is unclear and stratigraphic evidence from the mSRV suggests that the two ashfalls were separated in time (Dixon et al. 1985). In addition, tephra attributed to Hayes Volcano have been identified in other areas of southcentral and interior Alaska, and it is unclear if and how these tephra relate to the proximal Hayes tephra set H and the distal Watana tephra present in the mSRV. Loisel et al. (2013) also report on extensive 15–25-cm-thick tephra deposit in the Petersville Peatland area, north of Cook Inlet. Although this tephra layer has been identified as the having been erupted from Hayes Volcano, geochemical analysis could prove useful to evaluating the distribution and timing of individual tephra layers comprising the Hayes tephra set H. Likewise, the two tephra Schiff et al. (2008) report on from Bear Lake (south of Hayes Volcano), which are separated by 1.5 cm of gyttja, have not been geochemically analyzed and could prove useful for understanding the timing and direction of individual late Holocene Hayes tephra deposition. Recent analyses of tephra from lake cores in the Susitna area will also contribute to understanding the history and timing of tephra deposition in the area (Bigelow et al. 2015). Although Wallace et al. (2014) have tentatively correlated the Jarvis Ash bed, Tangle Lakes tephra, and Cantwell ash bed to their proximal tephra F, this research demonstrates that two eruptions of Hayes Volcano (Wallace et al. 2014 tephras F and H) were large enough to deposit tephra in the mSRV (upper and lower mSRV Watana tephra). While proximal tephra F is more likely to have been deposited farther than the mSRV, as the thickest deposit at the Hayes River Outcrop, future formal correlations may indicate whether the Jarvis Ash Bed, Tangle Lakes tephra, and Cantwell ash bed correlate to proximal tephra F or H of Wallace et al. (2014), or both.

The Devil tephra was not conclusively correlated with any one individual Hayes Volcano reference tephra from the Hayes River Outcrop (site 11HYKLW001); however, Riehle (1985) does report on a Hayes Volcano tephra from his sampling locality 27, 100 km northeast of Hayes Volcano, that is younger than the Hayes tephra set H. Riehle (1985) does not provide geochemistry for the tephra and no radiocarbon ages were obtained from the location, although an age estimate of between 500–2000 cal yr B.P. is provided. Because neither of the Hayes tephra set H reference sites—Riehle's (1985) site 23 and the Hayes River Outcrop (site HYKLW001) of Wallace et al. (2014) —have a representation of the younger tephra reported by Riehle (1985), sampling from another location proximal to Hayes Volcano could prove useful for correlating the Devil tephra to Hayes Volcano and understanding its distribution, which also has implications for contemporary hazard assessment of Hayes Volcano.

This study has used historic volcanic events and concepts of succession in Alaska to provided theoretical considerations of the impacts of tephra on the distal environment in the mSRV, and consequences for hunter-gatherers. While the focus in understanding the effects of volcanic events is often directed at proximal areas, consideration of the effects of tephra deposition on distal environments will aid in understanding prehistoric events (e.g. Waythomas 2015). Analyses of pollen and plant macrofossils below and above tephra in the mSRV looking for changes in plant structure could aid in understanding how tephra deposition impacted vegetation density and composition in different areas. For example, Long et al. (2013) examined non-arboreal pollen counts below and above Mt. Mazama ash erupted approximately 7630 cal yr B.P. and found that pollen counts were decreased following the eruption, taking approximately 50–100 years to return to pre-eruption percentages. Goetcheus and Birks (2001) also analyzed plant macrofossils below a 1-m-thick tephra on the Seward Peninsula of Alaska, in order to recreate the vegetation of the area prior to tephra deposition.

Research as to the seasonality of the tephra depositional events in the stratigraphy of the mSRV will allow for more refined considerations of the impacts of the events on the vegetation and ecology. For example, VanderHoek and Nelson (2007) synthesize various lines of evidence for the seasonality and impacts of the 3400 cal yr B.P. eruption of Aniakchak Volcano on the Alaska Peninsula. Close-interval pollen analyses provide information about the environment immediately before and after the eruption and tephra depositional patterns provide information about wind patterns at the time of the eruption, suggesting warm weather, which is supported by peat clasts and evidence for a tsunami (VanderHoek and Nelson 2007).

Lastly, as our understanding prehistoric hunter-gatherers in interior Alaska increases, so will our understanding of the effects of dramatic environmental changes on them. In the mSRV, the number of reliably dated cultural components is very small compared to the total number of archaeological components documented in the area, and future archaeological work in the area will aid in evaluating the cultural hiatuses of mSRV occupation suggested in this research. As archaeological research continues in interior Alaska and our understanding of changes in the environment through time are refined, the reason for discrete changes in archaeological assemblages through time may also become more apparent. Glacier and ice patch archaeology offer a means of addressing gaps in our understanding of subsistence patterns and organic technologies prior to the Athabascan Tradition (e.g. Dixon et al. 2005; Hare et al. 2004). Intersite analyses incorporating the locations of specific technologies and co-occurrence with specific fauna have provided correlations suggestive of technological function (Potter 2008a, for example); however, a better understanding of how specific technologies were utilized (e.g. there is not a current consensus on how microblades were used), especially within a settlement/subsistence system, will increase our understanding of prehistoric hunter-gatherer dynamics through time. Future considerations of the implications of how climate variation may have affected local resources may also aid in understanding the archaeological record of the mSRV. For example, caribou are present throughout the archaeological record of the mSRV and were an important resource being obtained in the area; dated cultural occupations in the mSRV appear less common in warm and dry periods of the mSRV and this could be related to caribou availability, as caribou prefer cooler climates.

7.2 Conclusion

This study is an important step in interior Alaskan archaeology, especially given conspicuous transitions in archaeological assemblages through time and suggestions and evidence of ashfall events being potential contributors to cultural change or hiatuses in other areas of Alaska and the Yukon (Black 1981; Dumond 1969, 1979, 2004, 2011; Moodie 1992; Mullen 2012; Saleeby 1984; VanderHoek and Nelson 2007; VanderHoek 2009; Workman 1974). While the cultural historical approach has been used to account for variability in archaeological assemblage characteristics through time in interior Alaska (Bacon 1987; Dixon 1985; West 1975, for example), recent analyses have synthesized multiple datasets in an attempt to understand the functional factors of variability and found it related to changes in subsistence and mobility patterns through time (Esdale 2008; Potter 2008c, for example). It is important to also evaluate the effects ashfalls in interior Alaska, especially with reference to the current understanding of transitions in interior Alaskan archaeology. Evaluation of the effects of ashfalls on prehistoric populations requires an understanding of the deposits themselves, and this study has refined our understanding of tephra deposits in the mSRV and their timing, in order to consider how their deposition may have affected hunter-gatherers. This study has demonstrated that tephra deposits in the mSRV are older than originally documented, with the Devil tephra being deposited between 1625–1825 cal yr B.P., the Watana tephras being deposited between 3360–4400 cal yr B.P., and the Oshetna tephra between 6570–7970 cal yr B.P. The upper and lower Watana tephra are correlated to proximal Hayes Volcano tephra present at the Hayes River Outcrop (tephras H and F, respectively, of Wallace et al. 2014), while the Devil and Oshetna tephra could be products of Hayes Volcano that are not present at the Hayes River Outcrop.

This study has also demonstrated that the deposition of volcanic ash in the mSRV could have constrained resource availability and affected resource predictability patterns through time. Although vegetation recovery could have been relatively rapid, on the order of a few years, as Griggs (1915) observed following the 1912 eruption of Novarupta-Katmai, a few years could be devastating to hunter-gatherer groups relying on specific resources (Cashman and Giordano 2008), especially in a marginal environment such as the mSRV. Particularly as it applies to caribou, ecological recovery could have taken decades if lichen were buried by tephra (Collins et al. 2011; Henry and Gunn 1991). However, a broad diet breadth and residential mobility patterns of hunter-gatherers likely mitigated the risk of resource shortages in the mSRV caused by tephra deposition. Patterns of ecological recovery likely varied between tephra depositional events in the mSRV, depending on both the magnitude of the event and thickness of the resulting tephra deposit, as well as the seasonal timing (Antos and Zobel 2005). Ecological recovery is difficult to quantify because it would have also been influenced by ash preservation patterns on the landscape, resulting in patchy and varied stages of vegetation recovery within the mSRV. The Watana tephras, as the thickest deposits in the mSRV, were most likely to have affected the mSRV environment, and were deposited during the Northern Archaic Tradition in central interior Alaskan archaeology. Although hiatuses in cultural radiocarbon dates from the mSRV are indicated after tephra depositional events, the dataset is extremely limited and future archaeological work in the area will aid in evaluating whether these hiatuses are genuine and if they are indeed related to tephra deposition.

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Appendix A

This appendix provides mSRV archaeological tephra sample information. Tephra samples were collected during investigations as part of the Susitna Hydroelectric Project (Dixon et al. 1985) and have since been housed in the University of Alaska Museum of the North archaeology collections. Sub-samples of most of the tephra were processed and analyzed as part of this research; however some samples did not contain size fractions large enough to facilitate analysis. EPMA geochemical analyses of these tephra samples may be found in the supplemental file, Mulliken_2016_thesis_supplemental, as both raw (Table S3) and normalized data with glass populations designations noted (Table S4).

Table A.1. Tephra sample locations and descriptions from the mSRV. Continues to next page.

AT Number[a]	AHRS Number[b]	UAF Accession Number[c]	Provenience[d]	Sample notes[e]	Analysis Notes[f]
AT-3181	TLM-027	UA81-243-0491	N101/E100, North Wall, 13-15 cmbsd	Upper "Devil" Pinkish-grey tephra	
AT-3182	TLM-027	UA81-243-0491	N101/E100, North Wall, 16-19 cmbsd	Middle "Watana" Lt. Brown tephra	
AT-3183	TLM-027	UA81-243-0491	N101/E100, North Wall, 20-22 cmbsd	Lower "Oshetna" Lt. Grey tephra	
AT-3184	TLM-027	UA81-243-0491	N144/E98 (40x40 test hole), strata 3	Upper "Devil" dark brown tephra	
AT-3185	TLM-027	UA81-243-0491	N144/E98 (40x40 test hole), strata 4	Middle "Watana" Super-oxidized black tephra	
AT-3186	TLM-027	UA81-243-0491	N144/E98 (40x40 test hole), strata 5	Middle "Watana" Oxidized dark brown tephra	
AT-3187	TLM-027	UA81-243-0491	N144/E98 (40x40 test hole), strata 6	Middle "Watana" brown tephra	Analyzed, low analytical totals.
AT-3188	TLM-027	UA81-243-0491	N144/E98 (40x40 test hole), strata 8	Lower "Oshetna" Grey tephra	
AT-3189	TLM-038	UA81-224-0035	N105/E97, South Wall, 40-49cm	Tephra sample #2, Watana?	
AT-3190	TLM-038	UA81-224-0036	N105/E97, North Wall, 41-43cm	Tephra sample #3, Devil?	
AT-3191	TLM-055	UA81-246-0013	Test 1, East Wall, 10-12 cmbs	Upper tephra - no associated carbon samples. Devil?	
AT-3192	TLM-055	UA81-246-0013	Test 1, 8-17 cmbs	Middle "Watana"	
AT-3193	TLM-055	UA81-246-0013	Test 1, North Wall, depth not given	Lower "Oshetna" - discontinuous over square	
AT-3194	TLM-088	UA81-248-0023	Test 1, 7-8 cmbs	Devils (upper grey)	
AT-3195	TLM-088	UA81-248-0023	Test 1, 13-15 cmbs	Watana (yellow brown)	
AT-3196	TLM-088	UA81-248-0023	Test 1, 17-19 cmbs	Oshetna (lower grey)	
AT-3197	TLM-088	UA81-248-0024	Test 2, 15-18 cmbs	Watana (?)	
AT-3198	TLM-088	UA81-248-0025	Test 2, 19-23 cmbs	Devils or Watana (grey tephra)	
AT-3199	TLM-089	UA81-247-0078	Test 1, South Wall, 16-19 cmbs	This sample is probably NOT tephra but a mixed silt loam with tephra, note flakes and bones associated	Analyzed, high K2O.
AT-3200	TLM-089	UA81-247-0078	Test 1, South Wall, 19 cmbs	This sample is possibly not volcanic but a culturally produced ash	
AT-3201	TLM-089	UA81-247-0078	Test 1, East Wall, 23-27 cmbs	It is probably a sample of the "middle Watana tephra"	
AT-3202	TLM-095	UA81-249-0073	Test 1, Unit 2	Likely Devil tephra, Oshetna absent	
AT-3203	TLM-095	UA81-249-0073	Test 1, Unit 2	Likely Devil tephra, Oshetna absent	

[a]Alaska Tephra Laboratory and Data Center identification number (AT #); [b]State Historic Preservation Office Alaska Historic Resources Survey number; [c]University of Alaska Museum of the North identification number; [d]Provenience information describes the specific location at the archaeological site that the tephra sample was taken from, cmbsd referes to cm below square datum; cmbd refers to cm below datum; cmbs refers to cm below surface; [e]Sample notes are descriptive information associated with the tephra sample, located either directly on the sample bag or in the museum catalog; [f]Analysis notes provide information specific to electron probe microanalysis done as part of this research.

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Table A.1. Tephra sample locations and descriptions from the mSRV. Continued from previous page, continues to next page.

AT Number[a]	AHRS Number[b]	UAF Accession Number[c]	Provenience[d]	Sample notes[e]	Analysis Notes[f]
AT-3204	TLM-095	UA81-249-0073	Test 1, Unit 3	Likely Watana tephra, Oshetna absent	
AT-3205	TLM-096	UA81-250-0007	Test 2, West Wall, 9 cmbs	Pinkish white (Devils)	
AT-3206	TLM-096	UA81-250-0007	Test 2, South Wall, 9 cmbs	Yellow Brown (Watana)	
AT-3207	TLM-096	UA81-250-0007	Test 2, South Wall, 13 cmbs	Grey with sand (Oshetna)	Not enough material to analyze
AT-3208	TLM-096	UA81-250-0007	Test Pit 2, 13 cmbs	Tephra from yellow brown tephra (Watana?) Sample #1	
AT-3209	TLM-096	UA81-250-0007	Test Pit 2, 14 cmbs	Tephra from lower gray tephra (Oshetna?)	
AT-3210	TLM-096	UA81-250-0007	Test Pit #1, South Wall, no depth	Tephra from yellow brown tephra (Watana?)	
AT-3211	TLM-096	UA81-250-0007	Test Pit #1, South Wall, no depth	Tephra from lower gray tephra (Oshetna?)	
AT-3212	TLM-097	UA81-252-432	Test 1, Unit 3, 17 cmbs	This is a pinkish white tephra - "Devils ash"	Not analyzed
AT-3218	HEA-00189	UA84-147-157	N103/E93, West Wall, 22-25 cm (unit 3A)	Fine silt/tephra, lt. brown/tan	
AT-3219	HEA-00189	011-266 Tephra sample	N499/E90, SE Quad, South Wall, 54-59 cmbs, level 6 (Above Feature 6)	Interpreted as Hayes tephra	
AT-3220	HEA-00189	014-163 Tephra sample	N499/E90, SW Quad, 64-69 cmbs, level 8 (Collected as control matrix in similar provenience to Feature 6)	Hayes Tephra	
AT-3221	HEA-00189	014-131 Tephra sample	N500/E94, 20-25cmbs, level 4	Devil tephra	
AT-3435	TLM-030	UA81-217-0032	Unit 5, #8		
AT-3436	TLM-030	UA81-217-0032	Test #1, Unit 5, b+a, #6		
AT-3437	TLM-030	UA81-217-0032	Test #4, Unit 4, #7		
AT-3438	TLM-030	UA81-217-0032	Test #1, upper ash unit #3, #5		
AT-3439	TLM-030	UA81-217-0032	Test #4, Unit #6, #9		Not much glass, few analyses
AT-3440	TLM-130	UA82-070 not catalogued	N95/E99, East Wall, 14-17 cmbd, unit 4	Unit 4 within Watana	
AT-3441	TLM-130	UA82-070 not catalogued	N97/E99, East Wall, 6-8 cmbd, Unit 4	Unit 4 within Watana	
AT-3442	TLM-143	UA82-083 not cataloged	N95/E100, South Wall, 12-14 cmbd, Unit 3	Devil tephra	
AT-3444	TLM-128	UA82-068 not cataloged	N92/E99, North Wall, 29-33 cmbd, Unit 3	Unoxidized Watana Tephra Sample	
AT-3445	TLM-128	UA82-068 not cataloged	N92/E99, East Wall, 19-23 cmbd, Unit 2	Devil tephra	
AT-3446	TLM-040	TLM-040, Unit 3-A (no UAF accession ID)	Unit 3-A (Dilley 1988)	Gray (5YR 5/1) silt loam; Devil tephra; powdery; numerous small charcoal fragments, abrupt lower contact	Size fraction too small to probe

[a]Alaska Tephra Laboratory and Data Center identification number (AT #); [b]State Historic Preservation Office Alaska Historic Resources Survey number; [c]University of Alaska Museum of the North identification number; [d]Provenience information describes the specific location at the archaeological site that the tephra sample was taken from, cmbsd refers to cm below square datum; cmbd refers to cm below datum; cmbs refers to cm below surface; [e]Sample notes are descriptive information associated with the tephra sample, located either directly on the sample bag or in the museum catalog; [f]Analysis notes provide information specific to electron probe microanalysis done as part of this research.

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Table A.1. Tephra sample locations and descriptions from the mSRV. Continued from previous next page.

AT Number	AHRS Number	UAF Accession Number	Provenience	Sample notes	Analysis Notes
AT-3447	TLM-040	TLM-040, Unit 4-A (no UAF accession ID)	Unit 4-A (Dilley 1988)	Very pale brown (10YR 7/3) loam; Watana tephra; powdert; typical oxidized zone absent; abrupt lower contact	Size fraction too small to probe
AT-3448	TLM-040	TLM-040, Unit 4-B (no UAF accession ID)	Unit 4-B (Dilley 1988)	Very pale brown (10YR 7/3) loam; Watana tephra; powdert; typical oxidized zone absent; abrupt lower contact	
AT-3449	TLM-040	TLM-040, Unit 5-A (no UAF accession ID)	Unit 5-A (Dilley 1988)	Brown (10YR 7/3) silt loam; decomposed organics and staining; numerous small charcoal fragments; abrupt lower contact	Size fraction too small to probe
AT-3450	TLM-060	UA81-206-0003	Test #1, 10 cmbs	Tephra sample: whitish gray	
AT-3451	TLM-060	UA81-206-0004	Probe D-1, 14 cmbs	Tephra sample: gray	
AT-3452	TLM-061	UA81-207-0008	Test #1, North Wall, 23 cm	Tephra sample	Size fraction too small to probe
AT-3453	TLM-061	UA81-207-0009	No sample information	Tephra sample	Size fraction too small to probe
AT-3454	TLM-062	UA81-208-0005	Test #1, 13-18 cmbs	Whitish grey - Devil?	
AT-3455	TLM-062	UA81-208-0006	Test #1, South Wall, 20-23 cmbs	Dark grey ash - Oshetna?	Size fraction too small to probe
AT-3456	TLM-069	UA81-215-0033	Test #1, 19-23cmbs	Tephra sample from directly below hearth. Lower tephra: Watana or Oshetna?	Size fraction too small to probe
AT-3457	TLM-091	UA81-254-0005A	Test 1, Unit 3, 25 cmbs, collected from wall	Tephra Sample #1, light gray tephra: Devil?	
AT-3458	TLM-091	UA81-254-0005B	Test 1, Unit 4, 15 cmbs	Tephra Sample #2, light brown tephra: Watana?	
AT-3459	TLM-091	UA81-254-0005C	Test 1, Unit 5, 40 cmbs	Tephra Sample #3, Oshetna?	
AT-3460	TLM-091	UA81-254-0005D	Test 1, Unit 5, 40 cmbs	Tephra Sample #3, Oshetna?	

[a]Alaska Tephra Laboratory and Data Center identification number (AT #); [b]State Historic Preservation Office Alaska Historic Resources Survey number; [c]University of Alaska Museum of the North identification number; [d]Provenience information describes the specific location at the archaeological site that the tephra sample was taken from, cmbsd refers to cm below square datum; cmbd refers to cm below datum; cmbs refers to cm below surface; [e]Sample notes are descriptive information associated with the tephra sample, located either directly on the sample bag or in the museum catalog; [f]Analysis notes provide information specific to electron probe microanalysis done as part of this research.

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Appendix B

This appendix provides information on the setting, testing, and composite stratigraphy for each of the mSRV archaeological sites with tephra samples that were analyzed as part of this study. Tephra sample descriptions may be found in Appendix A. All site information in this appendix has been directly digitized from Dixon et al. (1985), except information from HEA-189, which has been directly digitized from Wendt (2013). Note that although Munsell color notations are provided in stratigraphic unit descriptions, colors of stratigraphic profile units are not reflective of the Munsell notations. University of Alaska Museum of the North identification numbers are noted in parentheses for some of the samples or cultural materials mentioned. References to figures and tables in Dixon et al. (1985) are kept; however, they are placed in brackets because they have not been digitized thus are not found in this appendix.

TLM-027

Setting

The site is located on the south side of the Susitna River at the mouth of a stream which joins the Susitna River from the east, north of the mouth of Fog Creek. Situated on the summit of a discrete cone-shaped knoll, at an elevation of 487 m asl (meters above sea level) (altimeter: 1598 feet), approximately 100 m from the river margin, the site overlooks both the Susitna River and the mouth of the small clear water stream to the south. The knoll forms the end of a ridge which extends northeast towards higher ground. In all other directions the 30 m high knoll slopes steeply to the level of the Susitna River. The top of the knoll is approximately 20 m square, sparsely vegetated, and commands a good view in all directions, which is limited only by the tops of several trees rooted on the steep slopes below. The Susitna River is in view for 5 km downstream and 1.6 km upstream. The views westward across the river and eastward along the ridge system behind the site are restricted by hills about 800 m asl (2625 feet). Below the site there is evidence of terracing by the Susitna River. Tree growth on the slopes of the knoll is dense but only a few birch and aspen grow on top, along with dwarf birch, blueberry, Labrador tea, lowbush cranberry, mosses, and lichens. The vegetation at the base of the knoll changes from birch and aspen to black spruce, highbush cranberry, grasses, and sphagnum moss.

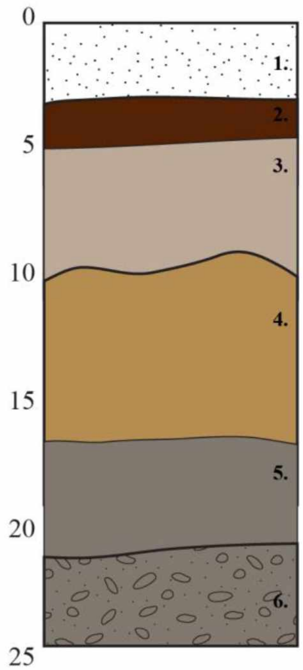
Testing

During the initial survey, this site was discovered through subsurface testing. No surface indication of the site was observed, however, cultural material was found in each of the three 40 x 40 cm test pits excavated ted on the relatively flat summit. Cultural remains were recovered from two different soil horizons in test pit 1, although test pits 2 and 3 yielded cultural material from the lower horizon only.

A grid shovel program was undertaken to assist in determining site size and the distribution of cultural materials. Forty grid shovel tests were excavated, *seven* of which yielded artifacts. Forty-eight argillite and three basalt flakes were recovered, as well as one basalt modified flake (UA84-218-2).

Results from the preliminary testing suggested that the site may encompass the entire top of the knoll and may contain vertically stratified cultural material bracketed by deposits of volcanic ash. To confirm these contentions three 1 x 1 m test squares were excavated at the site during the systematic phase of testing.

Depth (cm) Unit Description



1. Organic layer, roots, moss, lichen, and decomposed plant fragments. Continuous though variable in thickness.

2. Very finely divided organics mixed with silt; dark reddish brown (5YR 2.5/2). Variable in thickness and continuity. Contacts with unit 3 are both gradational and sharp.

3. A horizon/tephra (Devil). Variable in color depending on degree of alteration. Unaltered tephra is pinkish gray (7.5YR 7/2), while altered tephra is light brownish gray (2.5Y 6/2). Sharp lower boundary. Thickness variable throughout site.

4. Tephra (Watana). Variable in color depending on degree of oxidation; upper subzone dark reddish brown (5YR 3/4) highly oxidized with sand-sized concretions and grades into less oxidized zone strong brown (7.5YR 4/6) that in turn grades into unaltered tephra brownish yellow (l0YR 6/6). Forms sharp upper contact with unit 3. Unit 4 mixed with unit 5 in test squares N108/El01 and Nl13/El00 while in test square N10l/El00 the contact between units 4 and 5 is sharp

5. Tephra (Oshetna). Variable in color upper portions are brownish gray (10YR 5/3) that grade into a gray (10YR 5/1) tephra. Units 4 and 5 are separated by a thin charcoal layer in square N101/E100. Continuous although in squares N108/El01 and Nl13/E100 mixed with unit 4; pebble and granules from unit 6 are mixed with unit 5 in these two test squares. In square N100/El01 the contact between 5 and 6 is sharp but wavy.

6. Intermixed sand, pebbles, and granules; strong brown (7.5YR 5/8) to yellowish red (5YR 4/6). In square N101/E100 sandy layer between unit 5 and underlying granules and pebbles.

Figure B.1. TLM-027 composite stratigraphic profile and unit descriptions.

TLM-030

Setting

The site is located at an elevation of 482 m asl (altimeter: 1581 feet) on the south margin of Fog Creek upstream from the confluence of Fog Creek with the Susitna River. Situated on the point of a river terrace, the site is approximately 46 m above Fog Creek and overlooks the deeply incised bedrock canyon through which Fog Creek emerges to join the Susitna River. Fog Creek drains a large area including the Fog Lakes region and is a major tributary of the Susitna River. Below the site the creek is shallow with braided channels and is approximately 10 m wide. The site occupies the rounded bend of a continuous terrace where it changes from an east-west orientation, parallel to Fog Creek, to a north-south orientation parallel to the Susitna River. East of the site the terrace joins a ridge which rises parallel to Fog Creek. West of the site the terrace edge drops off steeply for 30 m to a broad, relatively flat, forested alluvial flood plain. The view from the site is primarily northeast up Fog Creek and west down Fog Creek to its mouth, encompassing a distance of approximately 1.5 km. Visibility in other directions is limited by the terrain and dense spruce forest.

Both Fog Creek and the Susitna River are easily accessible from the site. A deeply incised game trail traverses the terrace on which the site is located and continues eastward up the ridge. Scattered spruce and birch are present at the site but do not block the view. Lowbush cranberry, blueberry, Labrador tea, mosses, and lichens form the principal ground vegetation. The surrounding vegetation is a relatively dense lowland spruce-hardwood forest with white spruce and alder present along the creek.

Testing.

Testing at TLM 030 included systematic testing, survey testing, and grid shovel testing. [Figure D.22 illustrates the topography of the site area and the portions of the terrace that were examined during systematic and survey testing].

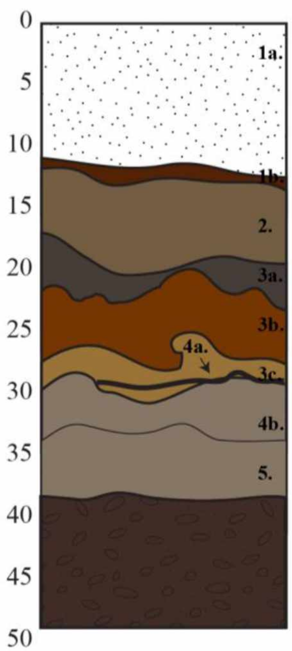
The site was initially found when artifacts were observed eroding out of the game trail that traverses the site. A complete basalt side-notched point (UAB0-77-520; [Figure D.3670]) was collected from the trail. Five test pits were excavated at the western end of the site, four of which produced cultural material.

Twelve 1 x 1 m test squares were excavated during systematic testing. The test squares were placed adjacent to one another and located on the northern edge of the terrace. At this location the terrace edge is oriented east-west paralleling Fog Creek. A series of 10 test squares were placed between two of the initial survey test pits (test pits 1 and 4). Square placement was designed such that one test square was superimposed over test pit 1 and another test square intersected test pit 4. An additional eight squares were placed between these squares in a configuration that would provide a continuous series of profiles between the two test pits. The objective of this square placement strategy was to clarify the relationship between two radiocarbon dates obtained from the two initial survey test pits and to ascertain the number, content, and stratigraphic position of the prehistoric component(s) reported at that time. Once excavation of the ten initial test squares was completed, two additional squares (105/E107 and N105/E109) were excavated. Excavation of these two squares was undertaken to resolve questions regarding the relationship of artifactual material to the stratigraphic sequence in this area of the

Testing subsequently conducted as part of the resurvey of survey locale 13 consisted of a number of shovel tests placed in the southern portion of the terrace from ca. 75–180 m, south of the main excavation area. The three shovel tests that produced subsurface artifactual material were expanded into 40 x 40 cm test pits. Additional shovel tests were placed along the western terrace edge, four of which produced artifactual material [Figures D.24 and D.25].

A grid shovel testing program was implemented to determine the areal extent of the Fog Creek site, and to clarify the relationship between the artifactual material in the main excavation area and subsurface material located during resurvey testing. A 10 x 10 m grid was established over the terrace using the systematic testing site grid, and shovel testing was conducted at 10 m intervals. Two hundred twenty-four shovel tests were excavated, ten of which contained artifactual material [Figure D.26].

Depth (cm) Unit Description



1a. Surface organic layer: fibrous root mat with living and partially decayed plant material from sphagnum moss, dwarf birch, Labrador tea, lowbush cranberry, and other herbaceous wood shrub vegetation at the surface. Varies in thickness from 1–29 cm, but is usually 8–12 cm. The lower boundary is clear and smooth to wavy. Nonmineral 01 horizon. Continuous surface cover across the excavation area. Layer is thickest in areas of sphagnum moss ground cover. Contains decayed wood and roots up to 5 cm in diameter.

1b. Fine silty sand with finely divided organic material, macroplant fragments, and rootlets; black (5YR 2.5/1). Varies in thickness from less than 1 cm to a maximum of 4 cm. Sharp and smooth to wavy lower contact. 02 horizon; peat layer with charcoal. In places unit 1b is undifferentiated from unit 1a, but the unit is generally continuous. Fibrous root material follows the contact between 1b and 2. Three basalt flakes were found within the unit, additional artifacts were recovered at the base of the unit along the contact with unit 2. A radiocarbon date of 170±90 years: A.D. 1780 was obtained from the unit.

2. Very fine silt size particles; varies in color from very dark gray (l0YR 3/1) to brown (l0YR 4/3) to pinkish gray (5YR 6/2). Variation in color may be due to downward leaching or organic material. Varies in thickness from 2–11 cm, but is usually 3–5 cm. Lower contact ranges from clear to indistinct and is very wavy and irregular. Tephra (Devil); eluvial A horizon. Unit is generally continuous and is present in all of the test squares. Unit is dense and compact. Artifacts are found at the contact and within this unit.

3. Very fine silt size particles; reddish black (l0R 2.5/1) to yellowish brown (l0YR 5/6). Massive unit that includes three subunits (3a, 3b, 3c) and varies in thickness from 3–27 cm with considerable variation occurring in individual test squares. The lower contact is sharp and wavy. Tephra (Watana); B horizon. Forms a continuous unit in all of the test squares with the exception of N106/E102. Absence of unit 3 in the northern portion of that square suggests that postdepositional erosion was active at the site. The unit frequently appears very mottled with 3a occurring predominantly at the upper extent and 3c at the lower extent. Variation between subunits may represent a continuum based on organic and iron accumulation and is related to soil-forming processes. Artifacts occur at the upper and lower contacts and within unit 3. Only 7 flakes are recorded from 3c.

3a. Very fine silt size particles with granular structure and some cemented concretions; reddish black (l0R 2.5/1) to dark reddish brown (5YR 2.5/2). Very irregular and wavy boundaries. Tephra (Watana); illuvial B horizon. Organic and iron accumulation. Often described as being mixed with unit 3b and 3c. Bioturbation observed in the form of ant colonies measuring up to 25 cm in diameter.

3b. Very fine silt size particles with granular structure; dark reddish brown (5Y 3/4 to 5Y 3/3). Contacts vary from sharp to diffuse. Tephra (Watana); illuvial B horizon. The sediment has a coarse texture, but peds will break apart and dry into a fine powder. Often occurs as large irregular mottles. Predominant subunit of unit 3.

3c. Very fine silt size particles that lack granular structure; yellowish brown (l0YR 5/6). Very wavy and irregular contacts with subunits 3a and 3b, sharp undulating contact with charcoal lens and unit 4b. Tephra (Watana); B horizon. Generally occurs at the lower extent of unit 3. Dries to a very fine powder. Charcoal lens: Small-medium size pieces of charcoal and carbonized plant material; black (10YR 2/1). Occurs as a lens less than 1 cm in thickness. Paleosol. Lens is discontinuous but found in all of the test squares. Bifurcates in some places. Appears as isolated charcoal concentrations at the upper contact of units 4a and 4b. Radiocarbon dates cluster between 3160 years B.P. to 3290 years B.P. for an inclusive range of 130 years.

4a. Very fine silt size particles; light yellowish brown (10YR 6/4). Unit is no more than 1 cm thick. Contacts are sharp and smooth. Occurs in isolated pockets directly beneath charcoal concentrations associated with the paleosol. Identified in six of the test squares. Greasy in texture when wet and dries to a fine powder. It is lighter in color although similar in texture to unit 4b beneath it. Unit does not contain artifacts.

4b. Very fine silt size particles; grayish brown (10YR 5/2) to very dark gray (10YR 3/1). Varies in thickness form 1-10 cm and is usually 3-5 cm. Extremes of thickness occur within individual test squares. The lower contact with unit 5 is clear and smooth. Tephra (Oshetna); buried eluvial horizon. Present in all test squares, although in some places it lacks continuity. In N104/E108 unit is possibly truncated. Matrix is greasy in texture. Variation in color appears to be the result of downward staining or leaching of charcoal from the paleosol. Contains some rounded pebbles at the lower boundary. Unit is at times subnormal to the surface and does not vary with surface slope. Abundant artifacts are located along undulating upper contact, at the lower contact and throughout the unit.

5. Very fine silt to clay size particles (plastic and sticky when wet) with small sand grains and occasional rounded pebbles; varies in color from grayish brown (10YR 5/2 -unit 5a) to dark yellowish brown (10YR 4/6 -unit 5b). Ranges in thickness from 1–16 cm although it is usually 4–6 cm. Contacts are clear and smooth, and generally less irregular than the overlying units. Cobbles and rounded pebbles frequently protrude into unit from the underlying unit (unit 6). Differentation between units 5a and 5b is based on color only. Unit 5a occurs at the upper portion of unit 5. Artifacts recovered from this unit were probably derived from unit 4.

6a. Very coarse sand, pebbles, and cobbles; dark reddish brown (5YR 2.5/2). Upper extent of glacial drift deposit; weathered. Poorly or very poorly sorted. The majority of the cobbles are rounded. Frost-shattered cobbles are present. The cobbles are usually 5–10 cm in diameter, reaching a maximum of 18 cm. Moderately developed unit with concretions and cementation of sand particles. Artifacts recovered from this unit probably derived from unit 4.

6b. Very coarse sand, pebbles, and cobbles; olive brown (2.5Y 4/4). Glacial drift. Similar to unit 5a but lacks concretions and is loosely consolidated. Excavation into this unit determined limit of excavation.

Figure B.2. TLM-030 composite stratigraphic profile and unit descriptions.

TLM-038

Setting

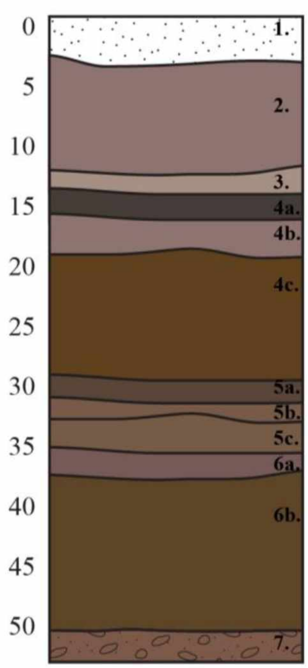
The site is located upstream from the mouth of Watana Creek on the eastern edge of a plain overlooking the creek from the west. Watana Creek is east of the site and ca. 152 m lower in elevation. A major unnamed tributary joins Watana Creek northeast of the site. Located at an elevation of ca. 762 m asl (2500 feet), the site is situated on a small discrete lobe of the continuous edge of the plain which trends east-west for 500 m before trending northward. The site overlooks a large stream terrace to the north and northeast approximately ca. 61 m lower in elevation, and the confluence of the unnamed tributary and Watana Creek to the northeast. East of the site the plain terminates and a sharp ridge with a series of prominent knolls descends 61 m to the level of the large alluvial terrace below the site. Access to the lower terrace and Watana Creek is possible but quite steep and difficult or impossible in places where downcutting has resulted in cliffs and steep bedrock exposures. The view from the site encompasses the relatively level plain westward from the site and the lower alluvial terrace and portions of Watana Creek and its tributary to the north and northeast. Only a small portion of Watana Creek *above* the confluence is visible from the site. Visibility in other directions is restricted by spruce forest and by slightly higher terrain to the south. Although not much higher than the surrounding plain, the site location affords a better view in more directions than other slightly lower lobes along the edge of the plain. The difference in potential views between this and other lobes (which were tested without finding cultural material) is subtle but apparently significant in terms of site location. On the north face of the lobe, a 2 x 2 m blowout has exposed whitish gray sand approximately 2 m below the site. Vegetation at the site consists of alpine tundra and high brush and a single isolated black spruce. Dwarf birch and willow, lowbush cranberry, crowberry, bearberry, moss, and lichens form the major ground vegetation. Scattered black spruce occur on the plain, southeast of the site, and alder occupy the ravines between lobes along edge of the plain. On the lower terrace to the northeast of the site spruce are denser and areas of muskeg are present.

Testing

No surface cultural material was observed at the site location. However, backdirt from shovel test 1 revealed 4 calcined long bone fragments from a medium-large size mammal. Three additional shovel tests and a test pit (test pit 1) were excavated in the immediate vicinity of shovel test 1 and one test pit (test pit 2) was placed 11.5 m southwest of test pit 1 [Figure D.37]. Shovel test 2 and test pit 2 did not reveal cultural material, however, shovel tests 3 and 4 and test pit 1 revealed extensive subsurface calcined faunal material in association with charcoal. No cultural lithic material was revealed by any of the subsurface tests.

Five 1 x 1 m test squares and an additional shovel test were excavated at the site [Figure D.37] in order to determine whether the charcoal associated with the burned faunal material represented a hearth or was natural in origin.

Depth (cm) Unit Description



1. Humus mixed with sand, organics not divided, 2–8 cm thick.

2. Poorly sorted unaltered eolian sand. Some non-divided organics present; grayish brown. (2.5YR 5/2). Lower boundary sharp.

3. Light gray (10YR 6/1) silty fine sand possibly mixed with tephra.

4. Silt (tephra or mixed with tephra). Dries to a light powder, 5–25 cm thick. Occurs in four subunits. Watana tephra (?).
4a. Very dark gray (10YR 2.5/1).
4b. Grayish brown (2.5YR 5/2) .
4c. Dark reddish brown (5YR 3/3) to dark yellowish brown (10YR 4/4).
4d. Brownish yellow (10YR 6/6).

5. Unsorted medium fine eolian sand. Occurs throughout site in a 3 to 15 cm thick unit. Lower boundary sharp. Consists of three subunits.
5a. Very dark grayish brown (10YR 3/2).
5b. Grayish brown (7.5YR 4/3) to dark yellowish brown (10YR 3/4).

6. Unsorted medium to fine eolian sand. Occurs throughout site. Thickness up to 40 cm. Lower boundary very abrupt. Consists of three subunits.
6a. Very dark grayish brown, dark grayish brown (2.5YR 4/2).
6b. Dark yellowish brown (l0YR 3.5/4).

7. Well-sorted medium sand, no soil development evident; olive (5YR 4/3). Possible lacustrine deposit.

Figure B.3. TLM-038 composite stratigraphic profile and unit descriptions.

TLM-040

Setting

TLM 040 is located on a resistant bedrock outcrop feature on the south side of the Susitna River, downriver from Kosina Creek. The terrain feature includes an isolated ridge with a terrace on its northeastern flank. The ridge is ca. 125 (northwest-southeast) x 20 m (northeast-southwest). It is bordered to the southeast by a small stream, and to the northwest by a channel of the Susitna River. South of the ridge is a relict river channel beyond which terrain ascends to upland areas. The ridge, at an elevation of 515 m asl (altimeter: 1689 feet), is approximately 20 m higher in elevation than the Susitna River, with bedrock exposures and steep colluvial slopes forming the margins of the terrace ca. 6–8 m below the ridge crest. The stream southeast of the site is ca. 50 cm wide, and both the stream and the Susitna River are accessible from the ridge. The topography of the ridge includes two high points with an intervening saddle, and a lower bench to the southeast. The view from the ridge is partially obstructed in all directions by the present vegetation. In the absence of this vegetation there would be an expansive view of the Susitna River.

Vegetation in the vicinity of the site is lowland spruce-hardwood forest with scattered birch and spruce trees on the ridge. The surface of the ridge is covered with a well-established vegetation mat including dwarf birch, sphagnum moss, lichens, grasses, Labrador tea, and low berry bushes. Surrounding vegetation is similar, although it is denser on the terrace northeast of the site and to the southwest in the relict river channel. A game trail runs along the crest of the ridge.

Testing

TLM 040 was located during survey testing when two flakes, one of which was modified (UAB0-147-1), were found in a shovel test located in the central high area of the ridge. Two 40 x 40 cm test pits were excavated in this area, with one of the test pits (test pit 1) superimposed over the shovel test that yielded artifacts. However, no additional cultural material was located.

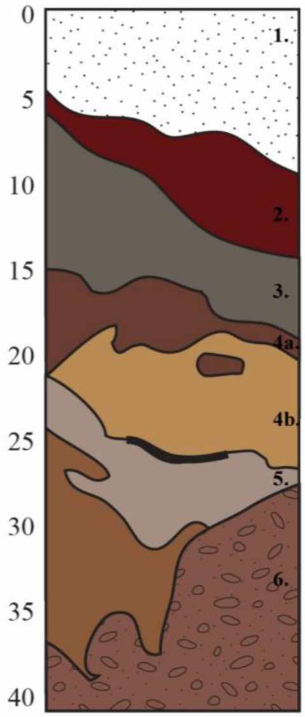
Systematic testing began with the excavation of three 1 x 1 m test squares (N80/E95, N83/E92, and N84/E95). Excavation of these test squares by natural stratigraphic units was considerably hampered by frozen ground associated with annual frost. Two additional test squares were opened (N83/E96 and N82/E95). Excavation of one of the test squares, N80/E95, was not completed as frozen sediment in that square was not penetrable.

In order to define the spatial extent of the site and more accurately clarify the stratigraphic context of artifactual material recovered during previous testing, the site was returned to when ground conditions were more suitable for subsurface investigation. A program of grid expansion shovel testing and additional systematic testing was implemented at the site. [Figures D.41 and D.42 illustrates the topography of the site and the location of shovel tests, test pits, and test squares].

Grid expansion shovel testing involved the excavation of shovel tests expanding out from the central area of the ridge with the test squares that contained artifactual material. Forty-five grid shovel tests were excavated in the central site area, 11 of which contained subsurface artifactual material. Fifty-five grid shovel tests were excavated in the northern area of the ridge, and 22 grid shovel tests in the southern area. Shovel tests in each of these areas produced artifacts. Grid expansion testing at TLM 040 was impeded by frozen ground. Of the 122 shovel tests initiated, 11 were not completed and are designated as frozen. Of the remaining 111 grid expansion shovel tests, 25 contained subsurface artifacts.

Additional systematic testing at the site consisted of re-excavating the test squares that contained artifactual material, completion of excavation of the test square opened during initial systematic testing (N80/E95), and the excavation of an additional test square (N81/E94). Review of the site stratigraphy and the excavation of the additional square were conducted to resolve questions regarding the stratigraphic position of artifactual material recorded during previous testing.

Depth (cm)



Unit Description

1. Surface organic layer: fibrous root mat with plant material from sphagnum moss, dwarf birch, Labrador tea, and other shrubs and grasses. Varies in thickness from 4–15 cm, but usually 5–10 cm. Lower boundary smooth and clear. Continuous surface cover across the site area.
2. Finely sorted organic material in fine-grained matrix, reddish black (l0R 2.5/1) with bands of very dark gray silt (5YR 3/1). Massive continuous unit varies in thickness from 6–15 cm. Contacts with underlying unit wavy and clear. 02 horizon with lenses of highly decomposed plant material, eolian sediment, and/or tephra. In some places distinct organic and silt lenses, which may represent buried O horizons, generally unit is intermixed silt and organics. Root disturbance extensive. Some charcoal present. Eight basalt flakes from shovel test, N97/El00, were in association with this unit.
3. Very fine silt size particles, varies in color from dark gray (l0YR 4/1) to dark reddish gray (5YR 4/2). Varies in thickness from 1–14 cm, although usually an average of 8 cm thick. Lower contact wavy and clear. Tephra (Devil); eluvial Ahorizon. Continuous unit in all of the test squares. Athermally altered rock from shovel test Nll7/E98 is the only artifact in association with unit.
4. Very fine silt size particles; dark reddish brown (2.5YR 3/4) to brownish yellow (10YR 6/6). Massive unit that includes two subunits (4a, 4b). Tephra (Watana); B horizon forms a continuous unit with 4a occurring predominatly at the upper extent and 4b at the lower extent variation between subunits may be a result of the accumulation of iron oxides and organic material. A single basalt flake was found at the 3/4 contact and 24 flakes of argillite and obsidian located at contact with underlying units. The 24 flakes may be derived from unit 5.
4a. Very fine silt size particles. Granular structure forming occasional small cemented concretions; dark reddish brown (2.5YR 3/4). Thickness of unit varies from 1–9 cm. The lower boundary is clear to diffuse and irregular in contour. Tephra (Watana); zone of accumulation. B horizon. Zone lacks continuity and often has a mottled appearance.
4b. Very fine silt size particles; color varies from dark yellowish brown (10YR 4/6) to brownish yellow (10YR 6/6). Unit ranges in thickness from 2–15 cm. Lower contact with unit 5 is abrupt and generally 3mooth. In the absence of unit 5 lower contact is clear to diffuse. Tephra (Watana), Bhorizon. Continuous unit. In places lies directly on the top of glacial boulders.
5. Very fine silt size particles with some sand; gray (10YR 6/1). Varies in thickness from 1–7 cm. Contacts vary from abrupt to clear and while the contour of the boundary is generally smooth it often plunges along the edges of large glacial boulders. Tephra (Oshetna) with fine sand particles. Unit generally continuous; although in areas of discontinuity, it is both lensed and mixed with unit 6. In some places this unit is overlain by a thin charcoal horizon; small charcoal flecks and pieces were found throughout unit. Bifurcation of the unit is apparant in some places. Numerous artifacts including flakes and blades are associated with this unit.
6. Silty-sandy matrix with some small cobbles present within and at the lower extent of unit. Color varies from a dark yellowish brown (10YR 4/4) to a dark brown (7.5YR 3/4). Unit is 1–8 cm thick. Where unit 5 is present the upper contact is sharp. In absense of a well-defined unit 5 mixing of 5 and 6 occurs and contact is clear to diffuse. Lower contact with unit 7 is gradual. Artifacts are associated with the upper contact and are also found within this unit. Artifacts include a lanceolate point (UA84-81-17), flake core, blades, flakes, and calcined bone fragments.
7. Sand to coarse sand with cobbles and boulders measuring up to 65 cm along longest axis; olive brown (2.5YR 4/4). Excavation into this unit determined limit of excavation. Glacial material. Frost shattering seen on a number of rocks. Grus was also common. No apparent polish observed.

Figure B.4. TLM-040 composite stratigraphic profile and unit descriptions.

TLM-055

Setting

The site is located north of the northwest tip of Tsusena Butte, and west of Tsusena Creek. It lies in a north-south glacial valley of about 500 m width, dominated by marshy terrain interspersed with ice stagnation topography. The site is situated atop a ca. 12 m circular knoll at the southern end of the valley, at an elevation of 756 m asl (altimeter: 2479 feet). This discrete knoll rises only about 2 m above the immediate surrounding terrain. The relief in the vicinity decreases in height to the east toward Tsusena Creek, and the valley wall rises in elevation to the west of the site. Site TLM 097 is northeast of TLM 055 and as it lies below the level of an intervening knoll it is not visible. Parts of Tsusena Creek are visible from the site, as is Tsusena Butte and the eastern valley wall of Tsusena Creek. Vegetation at the site consists of lichen, moss, dwarf birch, blueberry, lowbush cranberry, crowberry, and scattered spruce. The surface is uneven due to vegetation concentrations and differential soil deposition. Spruce trees are clustered in the poorly drained channels surrounding the site and on the slopes of the valley wall. The marshy plain to the east of the site is covered by muskeg.

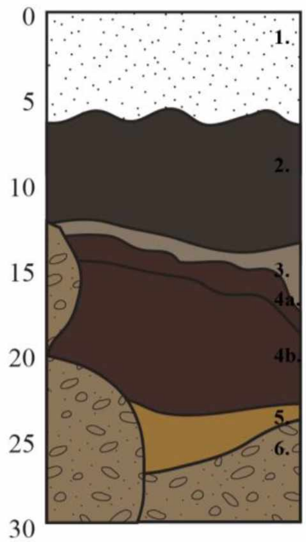
Testing

There are no surface indications of the site. However, a shovel test revealed a pale red rhyolite scraper (UABl-246-1; [Figure D.376h]) at 7 cmbs. In the subsequent test (test pit 1), four gray argillite flakes were found at 9 cmbs. An additional shovel test, dug prior to discovery of the site yielded no artifacts.

During the systematic testing of site TLM 097, TLM 055 was revisited and a single 1 x 1 m test square excavated at the site in an attempt to obtain additional diagnostic lithic material. Three very small chert flakes were the only lithic material recovered from this test square.

A grid shovel testing program was undertaken to assist in determining site size. A total of 23 shovel tests were excavated; however, none contained artifacts.

Depth (cm) Unit Description



1. Organic root mat: dwarf birch, Labrador tea, lowbush cranberry, mosses, lichens, blueberry, crowberry, and leaf cover. Thickness varies from less than 1 cm to greater than 6 cm.

2. Finely divided organics mixed with very fine grained silt; black (l0YR 2/1). Abundant charcoal flecks and pieces present with dark organics, possibly burned. Diffuse contact with unit 02 horizon, possibly mixed with tephras and/or eolian deposits in lower portion of unit. Basal portion may have very high concentrations of charcoal.

3. Very fine grained silt; grayish brown (l0YR 5/2), with pockets of dark brown (7.5YR 3/2). Devil tephra. Discontinuous, off knoll top.

4. Fine silt; dark reddish brown (5YR 2.5/2). Heavily oxidized. Oxidized Watana tephra. Upper contact clean. Lower contact with unit 4b gradational. Amount of oxidation variable.

5. Fine silt; yellowish brown (l0YR 5/6). Unoxidized Watana tephra. Upper contact with 4a gradation-al. Lower contacts clear. Unit 4 ca. 6 cm in depth.

6. Silt; brown (l0YR 5/3). Oshetna tephra. Silty sand where mixed with drift (unit 6). Unit ca. 4 cm in depth. Sand mixed with pebbles, cobbles, and boulders; dark brown (7.5YR 3/4) to dark reddish brown (5YR 3/3) where oxidized. Glacial drift.

Figure B.5. TLM-055 composite stratigraphic profile and unit descriptions.

TLM-060

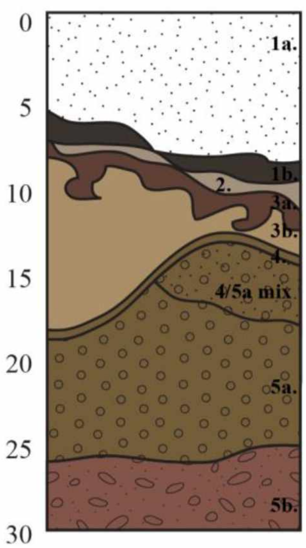
Setting

TLM 060 is located on the northwestern end of a long, high northwest-southeast trending kame, downriver from the confluence of Watana Creek with the Susitna River. The kame forms a 100 m long ridge, situated on the northern rim of Susitna River canyon, at an elevation of 663 m asl (altimeter: 2176 feet), is the highest and most prominent topographic feature of the kettle and kame terrain west of a tributary of the Susitna River, known locally as No Name Creek. From the site the view consists of the Susitna River and lower forested terrain to the east and north. There is a good view of a small (ca. 1 ha) kettle lake approximately 150 m to the west. Site TLM 061 is visible 300 m to the east, and TLM 171 is visible across the kettle lake on a kame of similar elevation 300 m to the west. The site, occupying the level, rounded top of the ridge at its northwestern high point, contains dwarf birch shrubs and scattered white spruce, paper birch, lowbush blueberry, and Labrador tea. The slopes of the kame are forested with spruce and poplar. The surrounding area is covered with a mosaic of dwarf birch cover and spruce woodland, with wetland vegetation surrounding the lake to the west.

Testing

The site was initially discovered when a black chert biface fragment (UA81-206-1; [Figure D.376i]) was found on the surface in a soil slump west of the ridge crest, approximately 15 m south of the northern end of the ridge. Eight shovel tests placed along the crest of the ridge resulted in the recovery of one argillite modified flake (UA81-206-2), about 15 m southeast of the surface find. Three 40 x 40 cm test pits placed on the site failed to produce any other cultural material.

A grid shovel test expansion program was conducted around the areas containing artifacts and one 1 x 1m test square, N124/E97, was excavated. The grid shovel testing program yielded no further cultural remains in the vicinity of previous finds, but a shovel test (N125.44/E100.25) produced three chert flakes near the northeast end of the ridge. Expansion around this test resulted in three other positive shovel tests yielding a total of eight chert flakes, one of which was modified (UA84-86-4). A total of 70 shovel tests were excavated during the grid shovel testing program. The 1 x 1 m systematic test square was placed adjacent to one of the positive tests in an effort to determine the nature and stratigraphic position of this portion of the site. [See Figure 0.74 for a map of the site and location of the test square and cultural materials].



Unit Description

1a. Continuous thick, dense layer of roots and organic debris, mixed with a small amount of silt. Varies between 2–12 cm thick, usually 5–8 cm. Contains a few small scattered pebbles. Contact with unit 1b is abrupt, wavy, with marked contrast in amount of roots. Units below 1b sometimes make contact with 1a in areas of localized uplift, around large roots.
1b. Very dark brown (10YR 2/1) to black (5YR 2.5/1). 02 horizon ·with humics, finely divided organics, silt, and occasional scattered pebbles. Varies in thickness from 1–6 cm, usually 2–3 cm. Continuous across square. Abrupt, wavy contact with 1a, abrupt to somewhat diffuse contact with unit 2 below. Contains some artifactual material.
2. Pale brown (10YR 6/2) to light brownish gray (10YR 6/3); well-sorted, very fine silt. Devil tephra. Discontinuous. Thickness variable, ranging from 0–3.5 cm, usually 1–2 cm. Sometimes mixed with units lb or 3. Upper contact abrupt to diffuse and wavy, lower contact usually diffuse and wavy broken. Both contacts and the unit itself contain artifacts, as well as a few scattered pebbles from drift.
3a. Dark reddish brown (5YR 3/3) silt to sand size particles, well sorted, the sand size particles probably cemented or coated silt particles owing to concretion with iron oxides. Illuvial horizon. Watana tephra. Mottled, grades into unit 3b below. Broken, diffuse, and discontinuous contact. Usually abrupt contact with unit 2, sometimes mixed with unit 2. Areally (sic) discontinuous, varying between 0 and 3 cm thick. Contains artifacts.
3b. Light yellowish brown (10YR 6/4) to yellowish brown (10YR 5/6) well-sorted, extremely fine silt, with scattered pebbles. Watana tephra. Discontinuous in area, varying between 0–9 cm. Often missing or mixed with glacial drift (unit 5). Diffuse contact with unit 3b and 5a, abrupt to diffuse wavy contact with unit 4. artifacts, especially at contact with unit 4.
4. Thin (less than 1 cm), highly discontinuous brown (l0YR 4/3) sandy silt with abundant finely divided charcoal flecks. Paleosol. Often mixed with units 3b or 5a, usually diffuse broken or wavy contact with unit 5, often missing entirely. Contains abundant pebbles and flakes.
5a. Dark yellowish brown (10YR 4/6) poorly sorted silty sand with abundant gravel, shale pebbles, and occasional rounded cobbles. Variably thick between 4 and 15 cm, usually 8–10 cm. Gradual contact with 5b below·, marking depth of weathered glacial drift. Continuous across square. Often mixed with units 3 and 4 above, usually diffuse contact with these units. Contains artifacts in upper part.
5b. Olive brown (2.5Y 4/4) unweathered poorly sorted gravelly sand. Glacial drift. Marks bottom of excavation.

Figure B.6. TLM-060 composite stratigraphic profile and unit descriptions.

TLM-061

Setting

The site is located west of Watana Creek on the northern border of the Susitna River canyon at an elevation of 628 m asl (altimeter: 2062 feet). It is situated at the summit of a discrete ca. 20 m high kame of conical form located northeast of the kame on which site TLM 060 is located. The site is near the center of the relatively flat summit of the kame, approximately 5 m southeast of the highest elevation which occurs at the northwest end of the summit. The top of the kame occupies an area of approximately 10 x 15 m with extremely steep slopes to the north and east. This is the highest point of land between site TLM 060 to the west and an unnamed tributary creek, locally known as No Name Creek, to the east. The view from the site is panoramic but somewhat obscured by fairly dense tree growth. Gradually rising terrain to the southwest limits the view to less than 500 m in that direction. A kettle lake of less than 1 ha lies approximately 500 m southwest of the site, but is obscured from view by intervening higher terrain. Immediately east of the site the terrain drops steeply ca. 90 m to the south-flowing tributary creek. Another eastward-flowing creek, originating as an outlet from the lake 2.3 km to the northwest, joins the southward-flowing tributary 300 m northeast of the site. These two creeks are not in view from the site due to the steepness of the terrain and fairly dense forest growth.

The terrain in the vicinity of the site is undulating and poorly drained with numerous kames and ridges and kettle depressions characteristic of ice-stagnation terrain. The Susitna River lies approximately 1 km south of the site at its closest point and is in view for approximately 6 km upstream to the southwest. The river is ca. 152 m lower in elevation and not easily accessible due to the distance and difference in elevation. The stream drainage to the east occupies a deep- "V"-shaped valley with exposed bedrock present. Two alluvial terrace levels are present on the west side of the stream below the site.

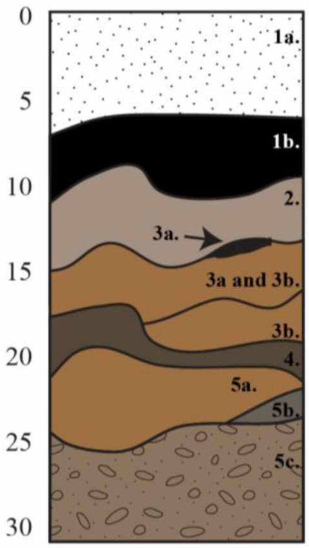
Vegetation in the site vicinity consists of low shrub and woodland white spruce. The slopes of the kame support a mixed birch, aspen, and spruce tree cover. The lower terrain around the base of the kame consists of sphagnum moss, grasses, and wet tundra with areas of marsh. Black spruce are also present on this wetter terrain. On-site vegetation consists of low shrubs including dwarf birch and blueberry. Aspen and birch occur on the slopes of the kame along with a few large white spruce. Bearberry, Labrador tea, moss, and lichen form a solid ground mat at the summit of the kame, which is relatively open with only low vegetation present.

Testing

A shovel test near the center of the kame's summit revealed subsurface charcoal and bone. This shovel test was expanded into test pit 1 which produced ca. 535 calcined medium-large mammal bone fragments. Charcoal and 15 fragments of thermally altered rock were associated with these bone fragments which occurred between 12 and 25 cmbs in two distinct soil/sediment units in test pit 1. This concentration of burned bone and charcoal in test pit 1 appears to extend to the southwest of the test. A single possible basalt flake was recovered from the backdirt of one shovel test prior to its enlargement into test pit 1. The shovel test adjacent to test pit 1 produced three small possible fragments of red ochre (UA81-207-4). Seven additional shovel tests were placed at the summit of the kame but none of these produced faunal material or charcoal. No cultural material was observed on the surface of the kame.

Systematic testing at TLM 061 consisted of the excavation of one 1 x 1 m test square and a grid shovel test expansion program. A total of 29 grid shovel tests were excavated, two of which produced cultural remains. In grid shovel test N100/E104 a basalt flake was found below the Devil tephra (unit 2) near its contact with the oxidized Watana tephra (unit 3a). In grid shovel test N102/E104 21 argillite flakes and six chert flakes were recovered from the organic silt (unit 1b), the contact between the organic silt and the Devil tephra (unit 1b/2), and the Devil tephra (unit 2). The majority of these flakes were recovered at the contact of the organic silt and Devil tephra (unit 1b/2). The one 1 x 1 systematic test square, N100/E102, was placed between test pit 1 and the positive grid shovel tests.

Depth (cm) Unit Description



1a. Surface organic layer, thick fibrous root mat with living and partially decomposed plant material from Labrador tea, blueberry, lowbush cranberry, sphagnum moss, low heath, and lichens. Varies in thickness from 3–11 cm, but is usually 7 cm. The lower boundary is clear and smooth. Continuous. 01 horizon.

1b. Very fine silt with decomposed plant fragments and rootlets; black (N 2/). Varies in thickness from 2–9 cm, usually 4 cm. Lower boundary clear and smooth to wavy. Continuous, 02 horizon with tiny flecks of charcoal present. Cultural material at lower contact with unit 2.

2. Fine-grained silt size particles; pinkish gray (7.5YR 6/2) to dark gray (N 4/) to very dark gray (N 3/). Ranges in thickness from 2–7 cm, but generally is 4 cm. Abrupt, wavy contact with unit 3a. Tephra (Devil); eluvial A horizon. Fairly continuous. Root penetration. Cultural.

3a. Fine to medium silt size particles, granular structure, friable; strong brown (1.5YR 5/6). Ranges in thickness from 2–4 cm. Lower boundary wavy to indistinct. Mottling and cryoturbation evident. Discontinous. Tephra (Watana); illuvial 82 horizon. Oxidized. Cultural.

3a and 3b. Fine to medium silt size particles, granular structure, friable; strong brown (7.5YR 5/6) to (7.5YR 5/8). Ranges in thickness from 2–7 cm, generally 4 cm. Lower boundary abrupt to wavy, but fairly distinct. Mottling and cryoturbation evident. Discontinuous. Tephra (Watana); illuvial B2 horizon. Some oxidation. Cultural.

3b. Very fine silt size particles; yellowish brown (10YR 5/6). Ranges in thickness from 2–7 cm, but is generally 6 cm. The lower boundary is clear and distinct. Tephra (Watana); illuvial B2 horizon. Discontinuous. Cryoturbated. Cultural.

4. Fine silt size particles mixed with sand; very dark grayish brown (10YR 3/2). Varies in thickness from 2–7 cm, generally 3 cm. Lower boundary clear to diffuse with a wavy discontinuous contact. Tephra (Oshetna); eluvial A horizon. Cryoturbated. Cultural material within this unit and its lower contact with unit 5a.

5a. Sand and silt size particles mixed with gravels; strong brown (7.5YR 5/6) to (7.5YR 4/6). Varies in thickness from 1–16 cm, generally 6–9 cm. Lower boundary gradual and distinct to diffuse. Glacial drift. Poorly sorted. Oxidized.

5b. Sand and silt size particles, gritty texture, granular structure; dark gray (l0YR 4/1). Varies in thickness from 1–11 cm, generally 2 cm. Possible percolation layer of decomposed slate. Glacial drift. Poorly sorted. Lower boundary distinct and wavy to straight. Present primarily in the southwest corner of the test square.

5c. Sand and silt with pebbles and cobbles; brown (10YR 5/3). Glacial drift. Poorly sorted. Cobbles are rounded, usually 4–8 cm in diameter. Frost feature present. Unit determined the extent of excavations.

Figure B.7. TLM-061 composite stratigraphic profile and unit descriptions.

TLM-062

Setting

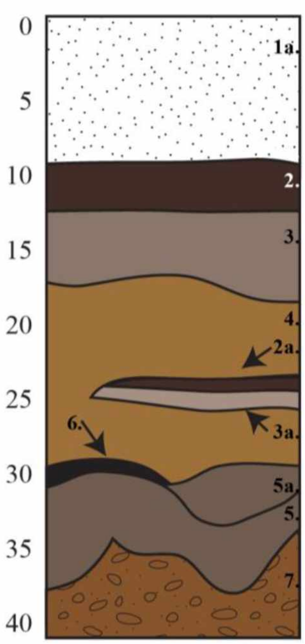
The site is located on the south side of the Susitna River west of the mouth of Kosina Creek. It is situated on the relatively flat, densely forested edge of a continuous alluvial terrace at an approximate elevation of 560 m asl (altimeter: 1836 feet). The site is on the extreme northeastern point of the terrace where it changes direction from an east-west trending terrace to a north-south trending terrace. The site elevation is ca. 60 m above the river level. The Susitna River is northeast of the site. The terrace point on which the site is situated is the highest and most prominent landform in the immediate site vicinity. Areas of exposed bedrock are visible on the steep eastern slope of the terrace immediately below the site location. The mouth of an unnamed creek, located east of the site, is not visible from the site due to the dense forest cover. The northern terrace edge slopes steeply down to a broad lower terrace level approximately 30 m lower in elevation. This lower terrace edge arcs northwest from the site following the Susitna River margin. The view from the site encompasses both the lower terrace to the northwest and the marshy wet tundra terrain below. The view extends across the Susitna River encompassing the mouth of the outlet stream from a small lake located northeast of the site on the north side of the Susitna River and the terrace and ridges in the vicinity of site TLM 033 which is directly across the river at almost the same elevation. A small, forested island is also visible east of the site at the confluence of the unnamed creek with the Susitna River. Site vegetation consists of open black spruce forest with birch and some white spruce present. Ground vegetation in the site vicinity includes dwarf birch, lowbush cranberry, Labrador tea, and a thick lichen and moss mat. Surrounding vegetation is open mixed forest which includes fairly dense birch and willow in the vicinity of the creek drainage to the east of the site. White spruce occurs on higher, better-drained ground and, primarily, black spruce occupies the flat terraces.

Testing

Initial testing at the site was restricted to the extreme northeastern edge of the terrace. One shovel test a gray chert flake core 17 cmbs within a matrix of whitish gray tephra. This test, expanded into test pit 1, also produced two fragments of a unifacially retouched red chert endscraper in the same matrix. Surface material collected at the site consists of a black basalt waste flake found on the top of the moss and lichen mat next to the southernmost shovel test. The provenience of this flake is unclear as it may have dropped out of the backdirt from this test. This test was enlarged into test pit 2 but no subsurface cultural material was observed. Intensive surface survey in the immediate vicinity of test 2 did not produce any additional surface artifacts.

Six additional survey shovel tests at the site were all sterile. Six 1 x 1 m test squares and 49 shovel tests were excavated during systematic testing. Five test squares were placed near the eastern edge of the terrace where survey testing had shown cultural material to be present. These tests were placed to define the extent and continuity of the site along the terrace edge and to obtain additional diagnostic artifacts and charcoal if possible. Shovel testing was conducted along east-west transects at 5 m intervals to define the western extent and boundary of the site. A grid shovel testing program was undertaken to assist in determining site size and the distribution of cultural materials. Thirty-one grid shovel tests were excavated, however, only one shovel test contained cultural material. Shovel test N94/E96 revealed a dense concentration of bone fragments in a mixed or cryoturbated Watana unit. This lens of bone matrix ranges from 24–29 cmbs, resting on the top of the Oshetna tephra.

Depth (cm) Unit Description



1. Organic with roots and rootlets; varies in color from very dusty red (2.5YR 2.5/2) to dark reddish brown (2.5Y.R 2.5/4). Varies in thickness from 2–17 cm. Small pieces of charcoal are occasionally present. Contact with unit 2 is gradational. O horizon.
2. Finely divided organics; black (5YR 2.5/1 to 10YR 2/1). Charcoal present in all tests and shovel tests with greatest concentration at contact with unit 3. Thickness varies from 2–9 cm. Lower contact with unit 3 gradational with some mixing. Greasy texture. A horizon. Cultural.
2a. Finely divided organics; black (5YR 2.5/1). Occurs only in test square N80/El03. Interpreted as buried unit 2.
3. Very fine silt; ranges from light brownish gray (l0YR 5/2) to light gray (10YR 7/1) with dark gray streaks (l0YR 3/1) at upper gradational contact with unit 2 where mixing occurs and charcoal flecks are present. Varies in thickness from 1–8 cm and is occasionally discontinuous. Sharp lower contact w1th unit 4. Occasional charcoal flecks present. Dries to a fine white powder. Devil tephra. Cultural.
3a. Very fine silt; light brownish gray (10YR 6/2). Occurs only in test square N80/E103. Interpreted as buried unit 3.
4. Very fine silt; ranges in color from dark reddish brown (2.5YR 2.5/4) in strongly oxidized upper contact with unit 3 to yellowish brown (10YR 5/6) or pale yellow (2.5Y 7/2) in lower portion of unit. Strongly oxidized zone discontinuous and mottled with granular texture. Oxidation gradational within unit. Thickness varies from 4–28 cm. Lower contact with unit 5 sharp and involuted. Watana tephra. Cultural.
5. Medium silt to sandy silt; varies in color from dark grayish brown (l0YR 4/2) to gray (10YR 6/1). Pebbles present, probably due to mixing with unit 6. Often overlain by thin discontinuous charcoal lense. Sharp but very involuted contact with unit 6. Oshetna tephra. Cultural.
5a. Fine silt; brown (10YR 5/3). Contains many charcoal flecks. Involuted and gradational contacts with units 4 and 5. Contains flakes and calcined bone fragments. only in test square N90/E95.5. Interpreted as mixing of units 4 and 5. Cultural.
6. Charcoa1 1ens.
7. Oxidized coarse sand, pebbles, and cobbles; ranges in color from strong brown 7.5YR 4/6) to yellowish brown (10YR 5/6). Unsorted. Glacial drift.

Figure B.8. TLM-062 composite stratigraphic profile and unit descriptions.

TLM-069

Setting

The site is located east of Jay Creek and north of the Susitna River at an elevation of ca. 792 m asl (2600 feet). The site is situated at the top of an elongated knoll in an area of glacially scoured bedrock. The knoll descends for a distance of 80 m from the site to the east-southeast at a 25-degree slope. To the west-northwest the knoll descends at a gentler slope for about 100 m. The site itself is on a discrete, flat-topped bedrock exposure measuring 20 x 30 m. Looking north from the site the view encompasses an unnamed creek drainage 700 m distant. To the east are three knolls ranging 150–200 m distant and 15–25 m higher in elevation than the site knoll. A drainage flows between them into a low, poorly drained area containing a small marshy pond which lies 50 m east-northeast of the site. Beyond these landforms to the east, the land rises sharply. To the south are three knolls ranging 100–750 m distant. The closest knoll is equal in elevation to the site knoll and the furthest southern knoll is the highest one in view at ca. 823 m asl (2700 feet). To the west the land descends towards the Susitna River in a series of knolls and drainages. The site knoll is unique in comparison to the other knolls described due to its low relief and its close proximity to three water sources: the Susitna River ca. 274 m below and to the southwest, the unnamed creek drainage to the north, and the pond to the east-northeast. Vegetation surrounding the bedrock exposure consists of dwarf birch, lowbush cranberry, and Labrador tea upon a lichen mat. A small stand of paper birch lies in a flat area at the base of the southwest side of the knoll. Spruce trees occur along nearby drainages. There are numerous grass species surrounding the pond area.

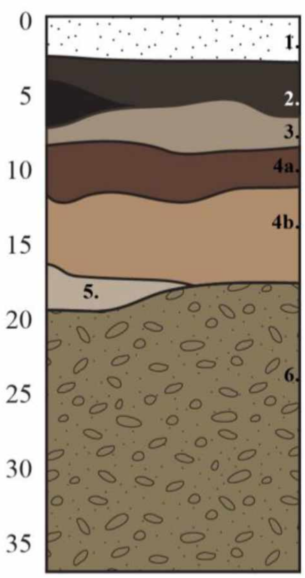
Testing

Site TLM 069 was located during survey testing. Several flakes and burned bone fragments were noted in one shovel test, and one black chert flake was noted in the other. Three flakes, lying in a discrete surface exposure, were also recorded, but left uncollected. Three test pits (40 x 40 cm) were excavated [Figure D.91]. Test pit 1 proved to be the productive, although each of the test pits yielded both lithic and faunal material.

Three 1 x 1 m test squares and three 50 x 50 cm test squares were initially excavated at TLM 069 during systematic testing [Figure D.91]. Test square N99/E101 was excavated near test pit 3 at the highest point of the knoll on which the site is located. Test N99/E112 was placed at the eastern end of the knoll to test the extent of subsurface cultural material east of test pit 1. Test square N100/El08 was excavated near test pit 1 at the north edge of the knoll. The three smaller 50 x 50 cm test squares (N99/El23, N99/E125, and N99/E136) were excavated on the eastern flank of the knoll to define the limit of subsurface cultural material.

Further testing at this site was undertaken to clarify the site stratigraphy and the extent of disturbances due to cryoturbation and slope processes. Three surface lithics were collected, two of which were of known provenience, as indicated on the site map. An additional three 1 x 1 m test squares were excavated. Placement of the test squares was intended to: 1) maximize the recovery of diagnostic cultural material in clear stratigraphic context (N99/E109), 2) to assess both downslope reworking of sediment units with associated cultural material, and 3) to further assess extent of the site (N99/E87 and N109/E120).

Depth (cm) Unit Description



1. Surface organic accumulation: roots and plant material from dwarf birch, cranberry, crowberry, lichen, and moss. Varies in thickness from 2–15 cm, modal thickness 2–3 cm. Lower boundary is abrupt. An 01 horizon. Generally continuous. Frequently truncated under tussocks by bioturbated sediments. Peatlike on wet slopes.
2. Silt with finely divided organics; black (7.5YR 2/0). 1–6 cm in thickness. Gradational contacts with underlying units. An 02 horizon. A thin horizon conforming to the present surface. Frequently truncated under tussocks by bioturbated sediments. Thicker and peatlike on slopes.
3. Silt; light brown to gray (l0YR 6/2), pink-tinged in fresh exposures. 1–3 cm in thickness. Abrupt upper and lower contacts. Devil tephra. Thin and discontinuous on the site kame, and occurs as pockets and stringers in colluvium on slopes. Frequently truncated under tussocks by bioturbated sediments. Some staining by illuvial organics.
4a. Sandy silt; dark red orange to red brown (5YR 3/3) 2–4 cm in thickness. Lower contact gradational. Oxidized Watana tephra. Absent on slopes, variably expressed on the kame top.
4b. Compact silty sand to silt; yellow brown (l0YR 6/4). 2–8 cm in thickness. Generally abrupt contact with underlying units, some mixing evident. Unoxidized Watana tephra. Generally continuous but absent or mixed by colluviation on slopes. Some pebbles or cobbles in the lower one-third of the unit.
5. Silty sand; gray (5Y 7/1). 1–3 cm in thickness. Abrupt upper and lower contacts where unmixed. Oshetna tephra. Discontinuous, occurring as lenses and pockets. May be mixed with units 4b and 6 by cryoturbation processes. Absent on slopes.
6. Coarse silty sand with pebbles, cobbles and boulders; grading from reddish brown to olive at depth (2.5YR 4/4 to 5Y 5/3). Unit not totally exposed. Contact with overlying unit 4b gradational to abrupt, with localized mixing. Glacial drift. Clasts are subrounded to angular. May be mixed with overlying units by colluviation on slopes.

Figure B.9. TLM-069 composite stratigraphic profile and unit descriptions.

TLM-088

Setting

Site TLM 088 is situated, at an elevation of 737 m asl (altimeter: 2418 feet), on an esker southeast of Tsusena Creek inside the right angle bend formed by the creek as it travels around the northwest slopes of Tsusena Butte. Tsusena Creek continues on its southward course west of the site. A series of three east-west oriented eskers are located north and northeast of the site, each with its northwest end truncated by Tsusena Creek. The highest feature in the immediate vicinity is an esker located ca. 30 m to the northeast of the site. This esker is ca. 2 m higher than the site and separated from by a ca. 5 m deep trough.

The esker on which the site was found is ca. 80 m long, oriented northwest-southeast, tapering from approximately 20 m wide at its northwest terminus, about 7 m above the level of the creek, to only ca. 6 m wide ca. 40 m down its length, eventually merging with the north slope of Tsusena Butte. A ca. 30 m, brush-covered strip separates the north end of the esker from the creek. This low-lying strip, only ca. 2 m above stream level, is wider on the west side of the esker as Tsusena Creek assumes an indirect path to the southeast. The site occurs in 6 m section of the esker approximately 40 m southeast and 50 cm lower than the abrupt northwest terminus. The esker makes a 35-degree dogleg to the south-southeast in the vicinity of the lichen-covered, wide area of the site. Two additional sites are located in the region. TLM 097 is located ca. 250 m west on a bluff being eroded by the opposite side of Tsusena Creek. TLM 081 is located on a low kame ca. 80 m to the north, but is not visible from the site. Being situated far back on the esker, the site affords a primary view to only the lower, brush-covered region to the south and west.

Vegetation at the site consists of an open lichen mat with Labrador tea, clumps of grass, blueberry, lowbush sphagnum moss, and reindeer moss. The predominant plant species in the vicinity is dwarf birch with small white spruce beginning to invade the region.

Testing

TLM 088 consists of a small 15 cm deep depression and subsurface lithics [Figure D.117; Table D.164]. Feature 1, southeast of test pit 1, is a 1 m (northwest-southeast) x 80 cm (northeast-southwest) rectangular depression. Given the small size of the depression, an initial 25 cm diameter shovel test in the feature was reexcavated, but not enlarged. Although no cultural material was found in this reexcavated shovel test, the profile indicates considerable subsurface disturbance not reflected in nearby test pit 1. Beneath the organic level in feature 1 is a mixed coarse sand, silt, and gravel zone. No underlying tephra units were identified in the depression, although three tephras were discernable in test pit 1. Test pit 1 revealed 22 black basalt flakes at a depth of 8–15 cm, in the Oshetna tephra. The feature 1 depression represents reuse of the site after the formation of the lithic scatter. No surface lithics were found.

A grid shovel testing program was implemented to locate subsurface material and to assist in determining the areal extent of the site. Seven shovel tests and 15 grid shovel tests were excavated, none of which yielded cultural remains. Observed site size based on the distribution of artifacts is 4 square meters [Table D.2].

No composite stratigraphic profile provided for TLM-088.

TLM-089

Setting

TLM 089 is situated at approximately 807 m asl (2650 feet) on the northern ridge of Tsusena Butte, a 1314 m (4310 feet) high butte which dominates the local landscape. This ridge overlooks a 6 km stretch of the "U" -shaped valley to the north through which Tsusena Creek flows southward toward the Susitna River. Tsusena Creek is 100 m below the site with its length visible from 3 km north to where it makes a right angle southwards around the base of the butte, adjacent to sites TLM 081, TLM 088, and TLM 097. The major northern ridge crest passes to the west and is separated from the ridge section on which the site is found by a narrow ravine. The site sits on a ridge segment which is 20 m across at the point where it merges with the main ridge 50 m south of its terminal bluff face. This minor ridge tapers from an average width of 15 m to only 5 m across at its abrupt termination 5 m above a 30-degree slope running down to the kettle and kame topography at the base of the butte. A series of six exposures, numbered from north to south, occur next to exposed bedrock on the ridge crest. Each of the exposures contained surface artifacts. From its location on the east side of the northern ridge, the site overlooks a 500 m wide marsh 50 m below with adjacent low-rolling terrain at the eastern base of the ridge. The kilometer long marsh drains both into Tsusena Creek to the north and into the north arm of Tsusena Lake, visible 800 m to the southeast. Vegetation at the site consists of lichen, clumps of grass, bearberry, cranberry, and dwarf birch. Low brush with scattered white spruce typifies the low-lying, surrounding terrain. Spruce trees are just beginning to colonize at the level of the site.

Testing

TLM 089 consists of artifact clusters from six sand and gravel exposures, as well as abundant faunal and lithic remains from test pit 1 [Figure D.118; Table D.165]. The six discrete exposures are nested between bedrock outcroppings, with outer limits of 25 (north-south) x 15 m (east-west). The exposures range in size from 3 x 5 m for exposure 1 down to only a 2 m square for exposure 3. Exposure 1, on the north slope near the termination of the ridge, shows extensive erosion with downslope displacement of artifacts. The exposures contained over a hundred black basalt flakes, the bulk of which were left in situ. A brown speckled, white chert biface fragment (UA81-247-3; [Figure D.379b]) was located in exposure 3. Other raw materials appearing on the surface are rhyolite and argillite of white, green, brown, and gray colorations. Test pit 1, located between exposures 3 and 4, uncovered a possible hearth containing numerous bone fragments and flakes in a thick charcoal unit and the overlying organic layers.

The 40 x 40 cm test pit was reduced to 20 x 40 cm at the 15 cm level due to the large quantity of material being recovered. Approximately 4000 bone fragments were recovered from this test. Most of the bone fragments had dimensions of less than 5 mm, although phalanx and metapodial fragments were sufficiently preserved for identification as caribou (Rangifer tarandus). Over 500 flakes of argillite, basalt, chert, rhyolite, and chalcedony were also recovered from the test. Estimated site size based on the distribution of artifacts is 375 square meters [Table D.2].

No composite stratigraphic profile provided for TLM-089.

TLM-091

Setting

Site TLM 091 is located on the southern end of a 1 km long north-south trending narrow bedrock ridge, north (350 degrees) of the highest point of Tsusena Butte. The ridge, composed of exposed blocks of granite, slopes gradually but irregularly downwards to the north into the Tsusena Creek valley, and falls off steeply to both the east and west. The site, composed of two loci, is located at ca. 883 m asl (2900 feet) on two sides of a saddle separating the high point of the ridge from Tsusena Butte. The two loci, recorded as a single site, occupy two very different settings in the saddle.

Locus A: Locus A is situated 20 m north of the low point of the saddle, on the eastern edge of the ridge. It is on the southern edge of a gently undulating, crescent-shaped area 25 (northwest-southeast) x 17 m (northeast-southwest), which is separated from surrounding terrain by abrupt slopes dropping 3–25m in all directions, steepest to the east. The surface of locus A is marked by numerous granite boulders and bedrock exposures, a small number of natural soil exposures, and a fairly continuous but low cover of lichens and dwarf birch.

Locus B: Locus B is located on the southern end of the saddle, ca.100 m to the south of locus A. It is situated on a steep (35-degree) rocky slope, 20 m above the elevation of locus A. The slope rises to the uplands leading to Tsusena Butte to the south and it is composed of talus boulders eroding from a steep bedrock butte. In the vicinity of the locus the talus slope is heavily vegetated with creeping shrubs and lichens.

From the site, the northern part of Tsusena Lake and the swampy area north of it are easily visible. Ranges on both sides of the Tsusena Creek valley are also visible, but terrain to the north and south, and the Tsusena Creek valley to the west, are obscured by higher ground. East of the site a small seasonal drainage flows eastward.

Testing

Locus A consists of 10 black basalt flakes located on the surface of a bedrock-soil exposure, in an area about 30 x 30 cm [Figure D.120, scatter 1]. Three of these flakes were collected [Table D.167]. Test pit 1, located 1 m to the south of site datum at scatter 1, contained no cultural material. Locus B consisted of an isolated black basalt lanceolate point tip (UA81-

254-4; [Figure D.379c]). No mapping or subsurface testing was conducted at this locus. Estimated size for locus A based on the distribution of artifacts is 4 square meters. Estimated size for locus B based on the distribution of artifacts is 4 square meters [Table D.2].

No composite stratigraphic profile provided for TLM-091.

TLM-095

Setting

The site, comprised of two loci (A and B), is located on the west side of Tsusena Creek north of Tsusena Butte in a confined, 1 km wide, north-south oriented glacial valley with steep talus slopes. The site is situated at 744 m asl (altimeter: 2442 feet) in kettle and kame topography on a discrete 6 m high kame which forms a low, rounded knoll covering an area approximately 60 m diameter. This knoll, composed of two summits separated by a low, wet channel, slopes very gradually westward for a distance of ca. 30 m to a grassy marsh with areas of standing water ca. 4 m lower in elevation than the site. Eastward the knoll slopes gradually to a flat gravelly flood plain terrace ca. 8 m lower where a shallow, south-flowing creek is located ca. 100 m from the site. Present visibility from the site is restricted by forest cover to less than 300 m and Tsusena Creek, located ca. 400 m east of the site, is not in view. Without the present tree cover, the view would be greatly increased and would include Tsusena Creek and the entire width of the valley floor. The entire surface of the knoll is occupied by dense ca. 1 m high shrub birch and scattered black spruce. The ground surface is covered with a mat of moss and lichen with bog blueberry, bearberry, and Labrador tea. Shrub birch becomes less dense on the lower slopes of the knoll. A dense spruce forest is located to the east between the site and Tsusena Creek but spruce are absent to the west where marsh grass and standing water are present. Five additional sites (TLM 084, TLM 085, TLM 087, TLM 094, and TLM 096) are located within a 1 kilometer radius of TLM 095 in the same general topographic setting.

Testing

TLM 095 was located by the presence of a basalt flake in one of the four survey shovel tests placed at the northwestern end of the knoll (locus A, [Figure D.124]. The positive shovel test at locus A was expanded into test pit 1. Forty-five fine-grained black basalt flakes and five black chert flakes were excavated 5–12 cmbs within or slightly above the Oshetna tephra which directly overlies the glacial drift.

One of the three shovel tests dug at the southern end of the knoll (locus B) also revealed cultural material and was expanded into test pit 2. Twenty-two fine-grained black basalt flakes, similar to those from test pit 1, were excavated from 7–14 cmbs associated with dark red oxidized Watana tephra and the reddish brown oxidized glacial drift [Table D.171].

A grid shovel testing program was implemented to assist in determining site size and the distribution of cultural material. Sixteen grid shovel tests were placed around test pit 1 (locus A), but none produced cultural material. Fifteen grid shovel tests were placed around test pit 2 (locus B), but none produced cultural material. Three grid shovel tests placed in the low trough between the loci and investigations of deflated areas on other aspects of the knoll also proved unproductive. Observed site size based on the distribution of artifacts is 8 square meters [Table D.2].

No composite stratigraphic profile provided for TLM-095.

TLM-096

Setting

This site is located north of Tsusena Butte and west of Tsusena Creek at the western edge of a marshy alluvial plain. It is situated on the top of a low, narrow, east-west trending ridge at an elevation of 744 m asl (altimeter: 2441 feet). The ridge is approximately 9 x 3.5 m and extends 35 m eastward into the surrounding flood plain. To the west the ridge rises gradually blending into the gentle slope (10 degrees) leading up to the base of the valley wall 200 m from the site. The creek valley east of the site is approximately 1 km wide and contains low ridges and kames on both sides of Tsusena Creek. Both the east and west valley walls are quite steep (30 degrees) rising ca. 609 m above the valley floor to an elevation greater than 1370 m asl (4500 feet).

Vegetation at the site consists of lichens, moss, blueberry, Labrador tea, and low dwarf birch. To the west on the lower valley slope and east along Tsusena Creek are dense stands of black spruce with occasional white spruce.

Testing

No surface artifacts were observed at the site, however, one argillite waste flake was found in a shovel test. This test was expanded into a 40 x 40 cm test pit (test pit 1) and a second 40 x 40 cm test pit (test pit 2) was excavated 6 m to the northeast. Test pit 1 revealed two additional argillite flakes [Table D.172]. These were found 6–9 cmbs in the uppermost of· three tephras present in the test, a whitish gray tephra directly below the organic zone (Devil). A charcoal lens was present at the contact between the middle light yellow brown tephra (Watana) and the lowest gray tephra (Oshetna). Charcoal sample (UA81-250-5) produced a date of 2750±215 years: 800 B.C. (DIC-2285).

Test pit 2 was sterile of cultural material but also contained a char- coal lens at the contact between the two lower tephras. Six shovel tests along the east-west top of the site knoll failed to reveal additional cultural material.

A grid shovel testing program was implemented to assist in determining the site size and distribution of cultural material. Sixteen grid shovel tests were placed around test pit 1, but none produced additional cultural material. Observed site size based on the distribution of artifacts is 4 square meters [Table D.2].

No composite stratigraphic profile provided for TLM-096.

TLM-097

Setting

This site is located in proposed Borrow Area C on the west side of Tsusena Creek northwest of Tsusena Butte. Located at the southern end of a 1 km wide north-south oriented glacial valley, the site is situated at an elevation of 750 m asl (altimeter: 2462 feet) at the top of an east-facing bluff which overlooks Tsusena Creek ca. 20 m lower in elevation. Terrain morphology in the site vicinity consists of kettle and kame topography with what appear to be north-south oriented eskers, associated with very irregular ridges and knolls on the east side of Tsusena Creek and a relatively level flood plain with only isolated kames on the west side of the creek. The valley walls rise steeply, at a greater than 35-degree angle, from ca. 762 m asl (2500 feet) to over 1371 m asl (4500 feet).

The landform on which the site is situated appears to be an outwash terrace which has been dissected by Tsusena Creek forming a steep east facing exposure. The steep valley wall begins ca. 100 m west of the site. The site directly overlooks Tsusena Creek and is located southwest of a sharp southeast bend in the creek channel. Access to the creek and the surrounding valley floor is excellent. Tsusena Creek is a clear 30–35 m wide smooth flowing channel less than 1 m deep with gravel bars and a slough visible northeast of the site. To the south drainages flow from the west wall of the valley forming a series of three confluences with Tsusena Creek. The northernmost of these confluences is southeast of the site. The field of view is panoramic with the depth of view greatest to the northeast overlooking a broad (300–400 m wide) alluvial plain. Forest cover restricts the view somewhat to the north but the steepness of the slope immediately northeast of the site affords an excellent overlook in that direction. Sites TLM 081, TLM 088, TLM 089, TLM 090, and TLM 091 located within 1 km of TLM 097, are concentrated on knolls and ridges to the east and are visible from the site.

Site vegetation consists of dense shrub birch and scattered mixed black and white spruce, with blueberry, Labrador tea, and a continuous mat of moss and lichen forming the ground cover. Dense stands of black spruce occupy poorly drained areas north of the site while muskeg and marsh grass predominate to the northeast in poorly drained areas of the alluvial plain.

Testing

TLM 097 was first recorded upon the discovery of a chert preform (UABl-252-1; [Figure D.379g] lying on the eroded face of a southwest exposure of the bluff edge. The preform, which was basally ground and thinned, was complete except for a fragment broken off the distal end. Intensive surface survey of the exposed bluff face produced an additional gray basalt flake ca. 20 m to the north on a northeast facing exposure at approximately the same relative position on the slope. Both of these artifacts were surface collected.

During survey testing, twelve shovel tests were dug along the top of the bluff edge and up to 30 m from the exposure. Two of these tests revealed subsurface cultural material and were expanded into 40 x 40 cm tests pits [Figure D.126]. Test pit 1, 40 cm in from the bluff edge, produced a total of 46 flakes, 1 bone fragment, and 1 thermally altered rock.

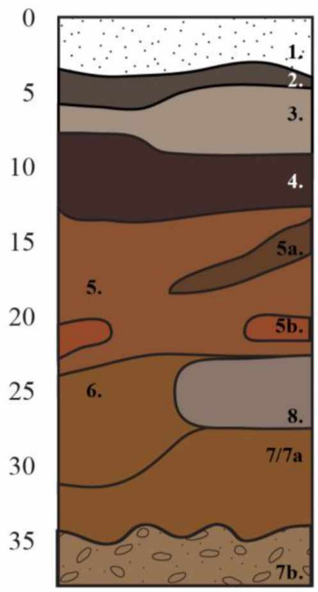
Test pit 2, located 6.5 m southwest of test 1, produced only a single gray fine-grained basalt flake which was recovered from the initial shovel test backdirt and has no stratigraphic provenience.

During the initial phase of systematic testing, five 1 x 1 m test squares and 24 shovel tests were excavated. Three 1 x 1 m test squares (N104/E103, N103/E105, and N98/E105) were placed near edge of the bluff where test pit 1 had produced subsurface cultural material. Another test square (N98.5/E100) was placed ca. 6 m from the bluff edge adjacent to test pit 2. One test square (N92.5/E80.5) was also placed ca. 30 m from the bluff edge between two shovel tests which produced cultural material. Shovel tests were dug at 5 m intervals on east-west transects in order to guide the placement of test squares and to help define the spatial extent and eastern boundary of the site.

Grid shovel testing was undertaken to assist in determining site size and distribution of cultural material. A total of 84 grid expansion shovel tests were excavated, ten of which produced cultural material.

Additional systematic testing at TLM 097 was undertaken to substantiate the existence and independence of two of the four cultural components initially identified at the site. A second goal of testing was retrieval of diagnostic artifacts from the upper cultural component represented by abundant basalt flakes, thermally altered rock, and hundreds of bone fragments. To carry out the testing, three additional squares were positioned in a checkboard fashion along the E104 grid line. These squares were designated N103/E104, N102/E103, and N101/E104. Three concentrations of artifacts are evident from the tests that produced cultural remains. One concentration is located on the eastern portion of the terrace close to the creek. Two 40 x 40 cm test pits, seven 1 x 1m test squares, and four shovel tests contained cultural material. A second concentration is located on the southwestern portion of the site. A single 1 x 1 m test square and shovel tests were excavated in this portion of the site. The final concentration in the northwestern portion of the site is defined on the basis of five shovel tests which contained cultural material.

Depth (cm) Unit Description



1. Surface organic mat consisting of sphagnum moss, dwarf birch roots, and peat. Varies from 1–19 cm in thickness. Lower contact abrupt and regular to wavy. 01 horizon.
2. Fine silty sand or silt loam with some clay; very dark gray (10YR 3/1). Generally very thin, between 0.5 cm and 6 cm thick. Possible 02, or humus, horizon. Well sorted with abundant humus and charcoal. Volcanic glass observed under 10 power magnification. Artifacts consist of sparse flakes, abundant charcoal, identifiable bone, and thermally altered rock.
3. Fine to coarse silt; color varies from pinkish gray (7.5YR 6/2) to dark brown (7.5YR 3/2). Ranges from 1–11 cm in thickness. Lower contact abrupt but often wavy and irregular. Tephra (Devil). Continuous across test squares. Well sorted and very friable. Contains many fine rootlets. Abundant volcanic glass; dries to a white powder.
4. Fine sand and silt; very dusky red (2.5YR 2.5/2). Thickness varies from 2–12 cm, generally being 4 cm. Lower contact is diffuse and gradational. Tephra (oxidized Watana); possibly a B2 horizon. Firm consistency with platy or granular structure. Moderately to well sorted, heavily oxidized. Volcanic glass observed. Rare basalt and chert flakes, possibly due to postdepositional movement from other strata.
5. Fine sand and silt, but with occasional granules; yellowish red (5YR 4/6). Thickness varies from 0.1–10 cm and is often interrupted by numerous rodent and root disturbances. Lower boundary often clear and nonwavy. Tephra (unoxidized Watana). Discontinuous. Generally well sorted but may contain coarse sand or granule size clasts. Very friable and dries rapidly to a fine powder. Volcanic glass observed. Rare basalt, argillite or gray chert flakes, possibly derived from other strata.
5a. Sandy silt with charcoal flecking and rootlets; dark brown (7.5YR 3/4). Discontinuous stringers of 1–2 cm thickness in N101/El04 and Nl02/El03. Contacts are poorly defined. Possibly the result of oxidation staining or rodent activity. Volcanic glass observed. Rare basalt flakes, probably derived from other strata.
5b. Fine silt lenses; red (2.5YR 4/8). Generally 1 cm thick, ranging up to 5 cm. Present at or near the base of unit 5 in N101/E104, and as diffuse staining in N103/E104. Volcanic glass observed.
6. Sandy silt containing occasional granules and pebbles; grayish brown (l0YR 5/2). Thickness of 2–10 cm, being generally 5 cm. Contact with unit 5 usually abrupt and wavy; contact with unit 7 abrupt to diffuse and regular to wavy. Often seems to be mixed with unit 7. Tephra (Oshetna). Discontinuous. Friable; poorly or very poorly sorted. Volcanic glass observed. Charcoal, abundant lithics found on or in this unit.
7. Gravelly sand and silts with numerous granules, pebbles, and cobbles; strong brown (7.5YR 4/6). Contact with unit 6 usually clear and regular, contact with unit 7a gradational. Glacial drift. Poorly sorted and friable.
7a. Same as unit 7, but often highly weathered and/or oxidized; very dusky red (2.5YR 2.5/4). Gradational upper contact, base of unit unexposed. Present in N102/E103 and N102/E104. Weathered and/or oxidized glacial drift.
7b. Loosely consolidated coarse to medium sand with occasional pebbles; strong brown (7.5YR 4/6) to yellowish brown (l0YR 5/4). Fluvial. Not present in all units.
8. Sandy silt containing granules, pebbles, some charcoal flecking, and organic debris; strong brown (7.5YR 4/6). Most contacts sharp and clear. Occurs as isolated pockets, probably the result of rodent activity: krotovina. Sparse cultural material present, probably derived from other strata.

Figure B.10. TLM-097 composite stratigraphic profile and unit descriptions.

TLM-128

Setting

TLM 128 is located on a level area at the intersection of two different ridge systems on the west side of Jay Creek northeast of the confluence of Jay Creek with the Susitna River. The site, at an elevation of ca. 836 m asl (2750 feet), is a prominent topographic feature higher in relief than the surrounding terrain. The two ridges which intersect at the site location include a major ridge system orientated in a northeast to southwest direction, roughly parallel to Jay Creek, and a minor ridge orientated in a northwest to southeast direction extending down toward Jay Creek. The level area is ca. 35 x 30 m in dimension and is situated on the southern and western portions of the two ridges, respectively. The topographic setting of the site vicinity is characterized by a glaciolacustrine plain with an undulating surface composed of ridges and knolls to the south, and bordered by upland hills rising to elevations of 1113 m asl (3650 feet) to the north and west. To the northeast and east the topography is similar to that in the vicinity of the site and includes the major ridge system.

The view from the site is essentially panoramic, obstructed only by higher terrain 200-300 m north and west. Particularly noteworthy is the view in southern directions from the southern part of the site. This view encompasses the glaciolacustrine plain with various terrain features and the area extending from the uplands down to the rim of the Jay Creek valley, in the vicinity of a mineral lick, 1.2 km southwest and 61 m lower in elevation. Site vegetation includes low brush and scattered spruce. Lowbush blueberry, cranberry, bearberry, and crowberry form the predominant site vegetation. Lichens, mosses, and grasses occur on the ground surface with soil exposed only in a few locations along game trails and in an 8 x 4.5 m exposure on the western edge of the site. Frost features were also observed particularly in the southwestern area where surface artifacts were located.

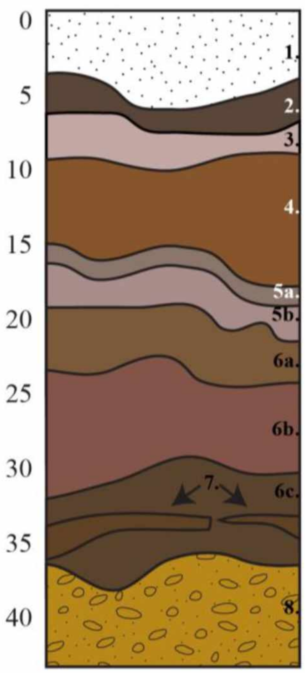
Testing

TLM 128 was initially located when an argillite biface fragment (UA82-68-3) was recovered from the southwest area of the site in a cryoturbated surface exposure. During survey testing of the site, one 40 x 40 cm test pit (test pit 1) was placed adjacent to this frost feature [as illustrated in Figure D.165]. Artifactual material was recovered from two stratigraphic levels within the test pit. In addition, a black chert modified flake (UA82-68-16) was collected from a soil exposure in the southeast portion of the site. Situated on the western slope of the site was a square depression which appeared to be the result of excavation into the slope. This 70 cm deep surface feature measured 1.7 square meters, and while slumpage had occurred, the depression had parallel and straight walls. The feature appeared to be recent in origin. Five shovel tests were placed on the level central area of the site, all with negative results.

Initial systematic testing at TLM 128 consisted of three 1 x 1 m test squares. These squares were placed in the vicinity of the surface erosional feature located on the southern portion of the ridge. The test squares were positioned in a checkerboard pattern with one of the squares superimposed over test pit 1. Placement of the three test squares was designed to provide a 3-meter continuous profile in an effort to define the content, extent, and stratigraphic position of artifactual material recovered from surface survey and in test pit 1.

Five additional test squares were excavated at the site. All test squares were excavated adjacent to one another to form a continuous 5- meter profile along the N89 grid line. This orientation was made to obtain information on the effects of slope erosion on stratigraphy. The 5-meter long excavation essentially truncates the ridge crest and reveals the sequence of sediment build up and subsequent deflation.

Depth (cm) Unit Description



1. Surface organic peat layer consisting of humus, roots, and plant debris mixed with fine silt and some eolian sandy silt; dark brown (10YR 3/3 moist; 10YR 4/3 dry). Thickness varies from 0–12 cm with a modal value of 4 cm. Lower contact generally distinct and regular to wavy. Discontinuous as a result of two game trails and other surface disturbances. Often mixed with unit 2 and in one case with both units 2 and 3. These mixed units are discontinuous and appear as pockets.

2. Fine silt with finely divided organics, fine charcoal pieces, carbon-staining, and some root debris; very dark gray to dark grayish brown (10YR 3/1 moist; 10YR 4/2 dry). Thickness is 0–6 cm with an average of 3 cm. Contacts are distinct to diffuse. 02 horizon. Unit is discontinuous and appears most often as a mixed unit with units 1, 3, or both 3 and 4. Disturbance present, due to the game trails, root invasion, and surface erosion, especially past the break in slope. Cultural.

3. Very fine silt with small charcoal flecks and some roots; light pinkish gray to gray (5YR 7/2 moist; 10YR 4/2 dry). Thickness varies from 0–5 cm with a modal value of 3 cm. Contacts are distinct to diffuse. Devil tephra. Intermittent, found mostly in pockets or as a mixed unit with units 1 and 2, unit 2, or with 2 and 4. Powders readily. Disturbance present due to game trails, root invasion, and surface erosion, especially past the breaks in slope. Flakes were found only in N92/E99.

4. Very fine grain silt with light oxidation and even coloration; strong brown to yellowish brown (7.5YR 4/6 moist; 10YR 5/8 dry). Thickness varies from 0–12 cm with a modal value of 4 cm. Contacts gradualw Watana tephra. Discontinuous and typically occurs as pockets. May be mixed with units 2 or 3. Some roots are present in this unit. Disturbances present due to root invasion and" surface erosion, especially over the breaks in slope. Cultural remains encountered in square N89/E98 are likely derived from other strata.

5a. Very fine silt with carbon-staining and decomposing organics; dark grayish brown to pale brown (l0YR 5/2 to 10YR 4/2 moist; l0YR 6/3 dry). Very thin, ranging from 1–2 cm. Lower contact vague. Paleosol. Found in the west wall of N89/E99 as well as the north wall of N90/E99.

5b. Fine to medium silt, powdery with no carbon; light brownish gray to pinkish gray (2.5YR 6/2 moist; 7.5YR 7/2 dry). Thickness varies from 1–3 cm. Contacts are generally distinct. Oshetna tephra. Discontinuous, typically occurs as stringers or small, isolated pockets; Also occurs as a mixed unit, with unit 4. Unit appears in all but N89/E100. One argillite flake was recovered from N90/E99.

6a. Fine sandy silt matrix, oxidized in upper portions; dark yellowish brown to brownish yellow (10YR 4/4 moist; 10YR 6/6 dry). Thickness varies from 2–15 cm with a modal value of 4–6 cm. Lower contacts gradual to indistinct. Oxidized eolian deposit. Fairly continuous throughout the site. Contains pockets of unit Sa in N89/E99. Disturbed by a mixed unit (units 6c, 7 and 8) and roots, especially noticeable in the south wall of N89/E100. Cultural material rare, likely derived from other strata.

6b. Fine sandy silt matrix, eolian deposit; olive brown to very pale brown (2.5YR 4/4 moist; 10YR 7/4 dry). Thickness varies from 0–18 cm with a modal value of 6–10 cm. Lower contacts gradual. Discontinuous and does not occur in the steepest portions of the slopes in N89/E97 and N89/El01. More consistent in color than units 6a or 6c. Mottled brown in some areas, which may indicate decomposed organics. Cultural material rare, likely derived from other strata.

6c. Very fine sandy silt matrix with prominent reddish yellow (orange) oxidized mottling throughout; dark brown to light yellowish brown (10YR 3/3 moist; 10YR 6/4 dry). Thickness varies from 0–14 cm with a modal value of 6 cm. Contacts generally distinct. Fairly continuous across site even over the breaks in slope. Unit 6c contains the major occupation unit of the site, unit 7. All squares except N92/E99 yielded cultural material.

7. Very fine silt, mottled in color which occurs within unit 6c; mottled dark to light brown (10YR 3/4 to 3/6 moist; I0YR 6/4 dry). Thickness is between 1–2 cm. Contacts generally distinct. Paleosol. Appears as discontinuous units of decomposed organics and fine charcoal pieces (unit 7a) and as oxidized lenses (unit 7b) which are red to strong brown (2.5YR 5/8 moist; 7.5YR 5/8 dry). Major cultural unit of the site.

8. Fine to coarse subangular gravels, poorly sorted pebbles and rocks; olive brown to light yellowish brown (2.5YR 4/4 moist; 2.5YR 6/4 dry). Typically 10 cm into this unit is the limits of the excavation. Glacial drift. Cultural remains only in N90/E99.

Figure B.11. TLM-128 composite stratigraphic profile and unit descriptions.

TLM-130

Setting

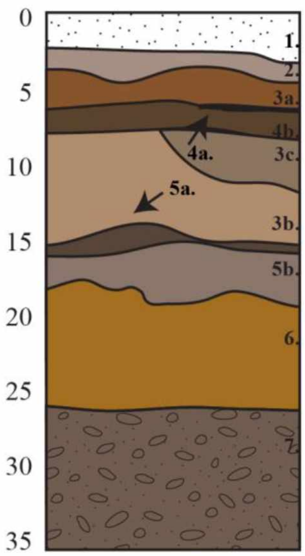
The site is located on a small knoll at approximately 671 m asl (2200 feet) near the southern rim of the Susitna River canyon, southeast of the confluence of Watana Creek with the Susitna River. The knoll, a northeast-southwest trending glacial kame about 30 x 7 m, and ca. 1 m high, is situated on a glaciolacustrine plain which slopes gradually up from the rim of the Susitna River canyon (north of the site) for a distance of about 500 m to merge with steep-walled uplands in the south. The plain is generally flat and boggy, but numerous knolls and ridges are located on it. These knolls and ridges range from 25–300 m in length and from 1–10 m higher than the plain, and provide dry areas within this boggy plain. The knoll on which TLM 130 is located is one of the smallest knolls in the area. Small drainages traverse the plain in a north-south direction; one of these lies 100 m to the west of the site, forming a small canyon to the northwest. A larger creek lies 250 m to the east, beyond a series of higher ridges and knolls. The view to the east is obstructed by these ridges which are ca. 6 m high. To the south and west the view of the boggy plain is partially limited by open black spruce forest and low knolls. The uplands to the south are clearly visible, and the Susitna River canyon (but not the river) is visible to the north. Vegetation on the site consists of fairly continuous lichen mat and low heath, with dwarf birch growing on the sides. Spruce are scattered about the sides, and make up open woodlands and thickets in the bogs away from the site, 60 m to the south. Gravel exposures and frost boils are rare.

Testing

During survey testing, an initial shovel test was excavated near the center of the knoll at TLM 130. This shovel test produced 15 pieces of burned bone and 6 flakes (of 3 different raw materials); it was later expanded to a 40 x 40 cm test pit (test pit 1), which yielded additional lithics and bone. A second shovel test was excavated at the north end of the knoll, but failed to produce cultural material. No surface artifacts were found.

Four 1 x 1 m test squares were excavated during systematic testing. The four test squares were located on the southern portion of the knoll. These tests were placed in a checkerboard pattern providing a 4 m continuous profile along the El00 grid line from N94 to N98. The placement of these squares was designed to define the cultural component(s) identified during survey testing and to obtain additional diagnostic artifacts.

Depth (cm) Unit Description



1. Organic layer: roots, crowberry, and lichen underlain by decomposed plant fragments and finely divided organic material. Dark brown (7.5YR 3/2). Continuous. Unit 1–4 cm in thickness. Contains charcoal. Clear to sharp contact.
2. Very fine silt size particles; light brownish gray (10YR 6/2). Contains small charcoal flecks and a small number of gravels. A horizon. Devil tephra. Variable in thickness and continuity. Clear to sharp contacts.
3a. Granular structure; strong brown (7.5YR 4/6). Watana tephra. Oxidized zone at upper extent, variable in color depending on degree of oxidization. Thickness varies from 1–3 cm. Sharp upper boundary.
3b. Very fine particles; light yellowish brown (10YR 6/4). Watana tephra. Unit 3a grades into unit 3b. Variable in depth but continuous throughout. Lower contact sharp.
3c. Very fine particles, cultural alteration with small amounts of charcoal and bone fragments. Variable in color from grayish brown (10YR 5/3) to yellowish brown (10YR 5/6). Watana tephra. Thickness from 7–9 cm. Discontinuous and does not extend into N97/E99. Similar in stratigraphic position to Unit 3a. Contacts clear to gradational.
4. Very fine silt size particles; grayish brown (l0YR 5/2) to light yellowish brown (10YR 6/4). Color variation may be due to cultural alterations. Varies from 0.5–1.5 cm. Discontinuous lens, present in all test squares, stratigraphically positioned between units 3a and 3b. Contacts clear. May represent a cultural surface.
4a. Fine-grained matrix; dark brown (l0YR 3/3). At upper extent of unit 4 contained numerous bone fragments, in addition to charcoal, and possibly organic material. Located only in N95/E99.
5a. Matrix with charcoal; dark grayish brown (10YR 3/2). Thin lens (less than 1 cm). Upper contact sharp. Lacks continuity but present in all squares.
5b. Granular structure with a small number of gravels; gray (10YR 5/1). Oshetna tephra. Varies from 1.5–3 cm in thickness. Discontinuous with undulating appearance. Clear contacts.
6. Sandy silty matrix with coarse sand particles and gravels; dark yellowish brown (l0YR 4/6) to yellowish brown (l0YR 5/8), depending on degree of oxidation. Oxidized glacial drift. Upper contact clear to sharp.
7. Medium to coarse sand with pebbles and cobbles; dark grayish brown (l0YR 4/2). Unoxidized glacial drift; unconsolidated. Unit determined limit of excavation.

Figure B.12. TLM-130 composite stratigraphic profile and unit descriptions.

TLM-143

Setting

TLM 143 is located at 786 m asl (altimeter: 2580 feet) on a broad, slightly undulating, gentle slope west of Jay Creek at the rim of Jay Creek canyon, north of the mouth of Jay Creek. The slope overlooks Jay Creek canyon just north of a very steep cliff face above a constricted meander of Jay Creek, and is approximately 150 m higher than the creek. The site lies on a kame at the edge of this canyon, with some material occurring on a moderately steep slope below the canyon rim leading into the steep canyon itself. The gentle slope descends gradually to the northeast; small linear kames, 1–2 m high and ca. 30 m long trending northwest-southeast, make the surface undulate slightly. This gentle slope is the northeastern edge of a large glaciolacustrine plain on the north side of the Susitna River. The plain has numerous kames on it, and generally descends southward in a gentle, undulating slope. The rest of this plain is not visible from the site due to intervening higher ground to the southwest. That part of the slope on which the site is located descends northeastward. Jay Creek canyon is seen meandering from the northeast to the south of the site. Jay Creek is not easily accessible from the site due to the steepness of the canyon to the south, although moderately steep ridges leading to the creek east of the site may provide access. A small, clear water stream flows 150 m north of the site at the bottom of a gentle slope. This is the nearest accessible water. Beyond this stream the Jay Creek uplands are visible. These uplands extend to the west, blocking the view in that direction. Located in the steep canyon area south of the site is a mineral lick visited by Dall sheep. Over a dozen archeological sites have been found within 1 km of this lick area. TLM 143 is covered with a moderately dense stand of dwarf birch and complete ground cover of lichen and low heath plants. Spruce, willow, and paper birch are scattered on the gentle slope above the canyon, and become fairly dense on the canyon walls. Game trails, rodent burrows, and frost boils provide a few areas of exposed sediments.

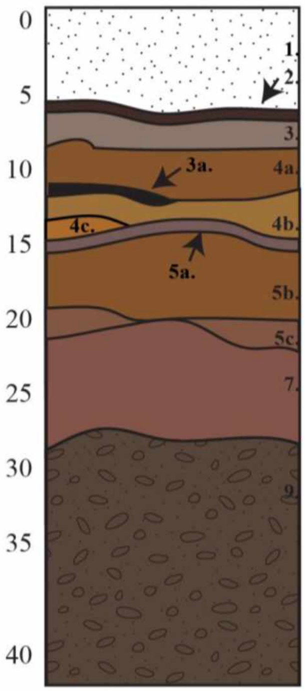
Testing

During survey, a sparse surface scatter of lithic material was encountered on the rim of the canyon and the edge of the gentle slope leading away from it. Twenty-five flakes, composed of argillite, basalt and chert, were noted on the surface within an area of 70 (northwest-southeast) x 20 m (northeast-southwest). Sixteen of these flakes were collected. These flakes were found in areas of surface exposure (game trails, rodent burrows, frost-boiled areas, and places of active downslope movement of material). A single 40 x 40 cm test pit (test pit 1) was placed on the southeast end of a small kame, 30 m north of the canyon edge. A dense layer of cultural material was encountered in this test pit.

Five 1 x 1 m test squares were excavated at the site during systematic testing. Three of the test squares were located on the southern of the kame in the vicinity of test pit 1. These test squares were placed in a checkerboard pattern providing a 3-meter continuous profile along the E100 grid line between N93 and N96, with one of the test squares superimposed over survey test pit 1. The placement of the test squares was designed to further define the cultural component encountered during initial survey. Two additional test squares (N71/E91 and N99/E79) were placed off of the kame to define stratigraphy and site extent.

Grid shovel testing was implemented at TLM 143 to assist in estimating site size and the relative density of artifactual material across the site. One hundred forty-two grid shovel tests were excavated, 42 of which contained cultural material. [Refer to Figure D.183 for the distribution of the test pit, test squares, and shovel tests].

Depth (cm) Unit Description



1. Organic layer: lichen, crowberry, and sphagnum moss underlain by poorly consolidated soil with roots and finely divided organic material; dark reddish brown (5YR 3/2). Thickness of organic unit is partially dependent on the type of surface organics, i.e., up to 16 cm in areas where surface organic material consists of sphagnum moss; to 2–6 cm in depth where lichen cover is on the surface.
2. Very fine sandy matrix with fine.ly sorted organic material and small charcoal pieces; black (5YR 2.5/1). Thin, discontinuous lens. Leaching of carbon and organic material into the underlying tephra was evident. Unit only present on the kame.
3. Very fine silt size particles consolidated by roots and rootlets. Variation in color dependent on degree of leaching; gray (10YR 5/1) to pinkish gray- (5YR 6/2). Tephra (Devil); A horizon. Continuous. Thickness varies from 1–5 cm. Sharp contact with underlying unit 4. Extensive reworking of this unit was evident in N71/E91. Small amount of charcoal observed.
3a. Fine grain organic matrix with small charcoal pieces; dark brown (7.5YR 4/2). Very thin, approximately 1 cm thick. Discontinuous lens stratigraphically positioned between units 3 and 4. Unit only observed in north wall profile of N94/E99.
4a. Fine to medium grain silt with medium to coarse sand size granule concretions in the most highly oxidized zones; strong brown (7.5YR 4/6 to 7.5YR 5/8). Tephra (Watana); B horizon. Generally continuous; 1–2 cm thick on the kame (N93/El00, N94/E99, N95/El00) and 1–10 cm thick off the kame (N71/E91, N99/E79). Sharp contact with the overlying strata. Oxidized zone at upper extent of tephra unit.
4b. Very fine silt size particles; yellowish brown (I0YR 5/6). Tephra (Watana). Gradational and undulating contact with oxidized tephra at the upper extent of unit. Identified in all test squares although reworking of soil was evident in N71/E91 and in N99/E79. Thickness varied from 1–11 cm off the kame to 1–6 cm on the kame. Generally continuous and horizontal appearance. Some mixing evident.
4c. Very fine silty matrix similar in texture and stratigraphic position to unit 4b although variable in color; strong brown (7.5YR 5/8). Identified only in N95/E100 stratigraphically positioned above 5a, above a concentration of charcoal. Possibly the result of thermal oxidization of unit 4b.
4d. Fine silty matrix with mixed and mottled appearance; brown (l0YR 3/3). Only identified in N71/E91 which had considerable evidence of reworking of the soil units. Discontinuous unit stratigraphically positioned above unit 4b, and varying in thickness from 2–21 cm.
5a. Fine silt size particles; dark grayish brown (2.5YR 4/2) to brown dark brown (l0YR 4/3). Culturally altered Oshetna tephra. Thin, 1–2 cm, continuous lens defined in test squares located on the kame. Sharp contact with overlying unit (unit 4). Defined on the basis of color, texture, and the quantity of artifactual material. Contains charcoal. Unit defines the upper extent of feature 2.
5b. Oxidized silt similar in texture to unit 5a; strong brown (7.5YR 4/6 to 7.5YR 5/8). Culturally altered Oshetna tephra. Continuous in test squares on the kame and associated with artifacts, thermally altered rock, and carbon. Varies from 2–6 cm in thickness and is associated with features 2 and 3. Sharp contact with unit 7 but diffuse elsewhere.
5c. Silty matrix which underlies unit 5b and associated with feature 3; reddish brown (5YR 4/4) to dark brown (10YR 3/3). Culturally altered Oshetna tephra. Contains numerous bone fragments, carbonized matrix, and thermally altered rock. Indistinctive unit observed in the east and south walls of N95/E100 and the north wall of N93/E100. Unit observed during excavation of N94/E99 not defined in profiles. Sharp contact with underlying units.
6a. Thin lens of organic matrix and charcoal; very dark gray (10YR 3/1). Varies in thickness from 1–3 cm and occurs at upper contact of unit 6b. Only defined in N71/E91.
6b. Very fine silt size particles; dark grayish brown (l0YR 4/2). Only defined in N71/E91. Tephra (Oshetna). Undulating and irregular appearance which may be the result of reworking of the soil and sediment units..
7. Silt size particles with some sand; olive brown (2.5Y 4/4). Continuous. Contacts vary from sharp to gradational; sharp upper contacts with unit 5b or 5c. Thickness varies from 1–10 cm on the kame and 4–20 cm off the kame. Sediment is possibly eolian in origin.
8. Fine silty organic matrix with charcoal; very dark gray (l0YR 3/1) to black (l0YR 2/1). Lacks continuity. Where present it is both thin (1 cm or less) and discontinuous. Possibly a buried soil. Located in N99/E79 and N71/E91.
9. Coarse sand with pebbles, cobbles, and small boulders. Maximum boulder size 35 cm. Majority of cobbles were rounded, 7–13 cm in diameter. Frost shattering observed but not extensive. Weathered rock and grus also observed. Excavation into this unit determined limit of excavation.

Figure B.13. TLM-143 composite stratigraphic profile and unit descriptions.

HEA-189 (from Wendt 2013)

Butte Lake is located in a low broad pass in the Chulitna Mountains that naturally links the Monahan Flat to the north with the Susitna River drainage to the south and forms the head waters of Butte Creek, a tributary of the Susitna River that flows roughly south. Butte Lake is approximately 3.5 kilometers long and 1 km wide, and is situated in a U-shaped valley at an elevation of 1022 m asl and is flanked on either side by summits ranging from 1220 m asl to 1581 m asl. The Butte Lake Northeast (HEA-189) site is located on a prominent kame and a peninsula in the northeast corner of the lake near an inlet stream that is presently dammed and forms a small pond (Figure 1-3). The site is above tree line, although spruce can be found scattered among vegetation otherwise associated with poorly drained kettle and kame topography deposited during Late Wisconsin glaciations.

Depth (cm) Lithostratigraphic Description

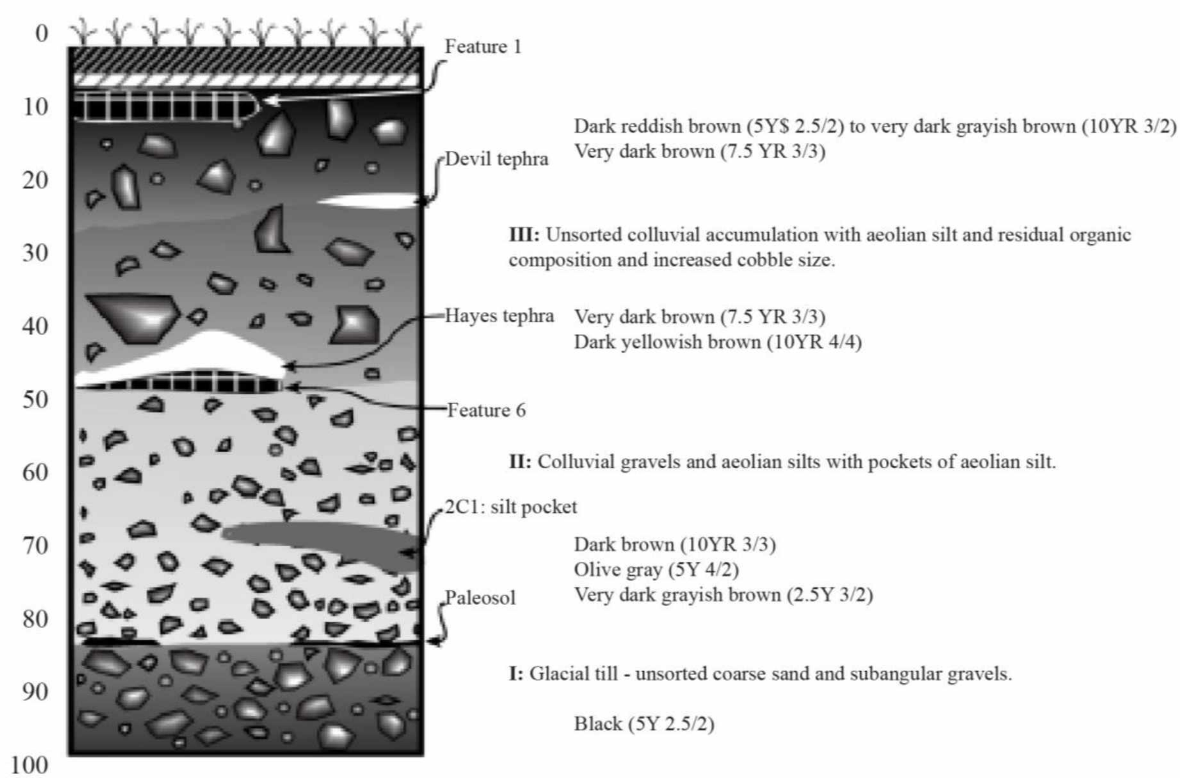


Figure B.14. HEA-189 composite stratigraphic profile and unit descriptions.

Appendix C

This appendix describes the process of correcting raw volcanic glass geochemical data obtained via electron probe microanalysis, prior to normalization. Working/secondary standards were routinely analyzed at the beginning and end of analysis sessions (typically five individual points of analysis on each standard), as well periodically during analysis sessions; standard analyses therefore bracket unknown analyses and because standards have published compositions (Table C1), they may be used to correct for instrument drift during the intervals bracketed by standard analyses. Correction methods were applied following that of Wallace personal communication (2015).

Analyses took place during two sessions, from January 29 to February 8 and from April 18 to 19, 2015. Standards Rhyolitic Glass 216 (USNM 72854 VG-568) and KN18 were analyzed as working standards for both sessions of electron probe microanalysis. Calculated averages of the points analyzed on standards throughout microprobe sessions were compared to published compositions of the standards in order to determine if corrections needed to be applied for individual oxides, which was generally determined if the published and analyzed values of oxides in standards differed by more than one standard deviation.

Table C.1. Published working standard compositions.

Standard	SiO_2	TiO_2	Al_2O_3	FeO_T	MnO	MgO	CaO	Na_2O	K_2O	P2O5	Cl
Rhyolitic Glass 216 (USNM 72854 VG-568)	76.71	0.12	12.06	0.8	0.03	0.09	0.5	3.75	4.89	0.01	0.13
KN18	74.6	0.18	10.52	3.54	0.07	0.02	0.01	5.68	4.39	nr	0.37

nr: not reported

Working standards were available through the University of Alaska Fairbanks Advanced Instrumentation Laboratory.

If corrections were necessary, they were calculated for individual oxides based on the type of difference from the standard value for that oxide. Straight corrections are applied when analyzed secondary standard compositions are systematically higher or lower than the published compositions, whereas linear corrections are applied when there are linear trends (typically caused by instrument drift) in analyzed secondary standard compositions. If a particular oxide exhibited routinely higher or lower values than that oxide in the published standard composition, then a correction would be calculated to bring the values closer to the published oxide value in that standard. This correction value was determined by dividing the published value of the oxide in that standard by the average analyzed value of the oxide in that standard. The correction value was then multiplied by the values of the oxide in the unknown tephra analyses which the standards bracketed.

If a particular oxide exhibited drift in that the values became progressively lower or higher throughout the analysis, then a linear correction would be calculated by plotting the analyses of that oxide vs time and calculating a linear regression. The linear regression would then be used correct the values for that oxide, by dividing the measured value of the oxide by the linear regression equation, and plugging in the line number of analysis for x. All corrections were applied to the unknown analyses that the standards bracketed, and the process was repeated for every series of unknown tephra analyses bracketed by analyses of working standards.

For the first session of electron probe microanalysis, from January 29 to February 8, 2015, Rhyolitic Glass 216 (USNM 72854 VG-568) was used to calculate corrections for SiO_2, Al_2O_3, CaO, and K_2O; a correction for FeO_T was calculated from the analysis of KN18 (Table C2). All corrections were applied because analyses were too high or too low rather than due to drift. For the second session of electron probe microanalysis, from April 18 to 19, 2016, Rhyolitic Glass 216 (USNM 72854 VG-568) was used to correct Al_2O_3, FeO_T, CaO, K_2O and Cl (Table C3). In most instances, oxide values were routinely higher or lower than published values of the oxide in the standard; however, some drift was indicated in values of SiO_2 and Na_2O for line numbers 3124 through 3471.

Table C.2. First UAF electron probe microanalyzer session corrections: January 29 to February 8, 2015.

Line Numbers	SiO_2	TiO_2	Al_2O_3	FeO_T	MnO	MgO	CaO	Na_2O	K_2O	P2O5	Cl
71 to 1690	0.999	-	0.976	1.02	-	-	1.173	-	0.965	-	-
1841 to 3101	0.995	-	0.966	1.02	-	-	1.167	-	-	-	-
Standard	**VG-268**		**VG-268**	**KN18**			**VG-268**		**VG-268**		

Tephra were analyzed on the JEOL JXA-8530X electron microprobe at the University of Alaska Fairbanks Advanced Instrumentation Laboratory.

Table C.3. Second UAF electron probe microanalyzer session corrections: April 18 to 19, 2015.

Line Numbers	SiO_2	TiO_2	Al_2O_3	FeO_T	MnO	MgO	CaO	Na_2O	K_2O	P2O5	Cl
3124 to 3471	$y=-0.0034x +88.397$	-	0.961	1.098	-	-	1.147	$y=0.0034x -7.9406$	0.964	-	1.312
3472 to 3746	-	-	0.961	1.098	-	-	1.147	-	0.964	-	1.312
Standard	**VG-268 for all**										

Tephra were analyzed on the JEOL JXA-8530X electron microprobe at the University of Alaska Fairbanks Advanced Instrumentation Laboratory.

Appendix D

This appendix provides a comparison of Hayes River Outcrop glass geochemical data obtained as part of this study to that of Wallace et al. (2014). In addition, similarity coefficients between mSRV archaeological tephra and Wallace et al. (2014) Hayes River Outcrop analyses are provided to justify re-analysis of the Hayes River Outcrop tephra as part of this study.

In general, Hayes Volcano proximal tephra glass geochemistries reported in this study are comparable to those reported by Wallace et al. (2014) and overlap within the range of one standard deviation for major-element oxides. However, there are discrepancies between the datasets. The primary geochemical population in proximal tephra F2 differs by greater than one standard deviation between the analyses done as part of this study and those of Wallace et al. (2014). Whereas this study reports one primary glass populations in tephra F2, averaging ~72 weight percent SiO_2, and a single point of analyses with ~69 weight percent SiO_2, Wallace et al. (2014) report a single glass population in proximal tephra F2, averaging ~74 weight percent SiO_2. Proximal tephra A also contains discrepancies between glass averages: this study reports two populations with ~69 and ~72 weight percent SiO_2, as well as a minor population with ~74 weight percent SiO_2; Wallace et al. (2014), however, report two glass populations with averages of ~70 and ~76 weight percent SiO_2, and a minor glass populations with ~72 weight percent SiO_2.

Despite general similarity between proximal Hayes Volcano similarity coefficients calculated between glass averages from analyses of the same tephra samples reported by Wallace et al. (2014) and in this study were all <0.95 (Table D2), although analyses were done on the same samples and mounts. In addition, none of the similarity coefficients calculated between archaeological mSRV tephra and glass averages reported by Wallace et al. (2014) were ≥0.95 (Tables D3, D4). None of the glass geochemical populations in archaeological Oshetna mSRV tephra samples had similarity coefficients ≥0.90 with any of the glass geochemical populations identified by Wallace et al. (2014) in proximal Hayes Volcano analyses from the Hayes River Outcrop.

These results demonstrate that re-analysis of the proximal Hayes Volcano tephra from the Hayes River Outcrop (of Wallace et al. 2014) was advantageous for the correlation efforts of this study.

Table D.1. Comparison of proximal Hayes Volcano tephra analyses reported in this study and in Wallace et al. (2014). Continues to next page.

Sample Name[a]	AT-#[b]	Unit[c]	Reference[d]		SiO_2	TiO_2	Al_2O_3	FeO_T	MnO	MgO	CaO	Na_2O	K_2O	Cl	P_2O_5	$TOTAL_{raw}$	n
11HYKLW001-11	AT-2564	H2	This Study	mean	74.48	0.24	13.50	1.83	0.08	0.44	2.39	3.87	2.64	0.55	0.06	98.69	35
				1 δ	*0.90*	*0.04*	*0.43*	*0.16*	*0.04*	*0.05*	*0.25*	*0.51*	*0.24*	*0.07*	*0.07*	*1.23*	
	AT-2564		Wallace et al. 2014	mean	75.36	0.22	13.73	1.61	0.08	0.42	2.06	3.51	2.57	0.40	0.05	97.32	25
				1 δ	*0.61*	*0.04*	*0.33*	*0.18*	*0.04*	*0.04*	*0.18*	*0.29*	*0.13*	*0.06*	*0.03*		
11HYKLW001-10	AT-2563-P1	H1	This Study	mean	74.45	0.25	13.37	1.83	0.06	0.43	2.42	4.17	2.45	0.57	0.08	98.88	29
				1 δ	*0.72*	*0.03*	*0.24*	*0.25*	*0.03*	*0.05*	*0.19*	*0.48*	*0.09*	*0.08*	*0.11*	*1.33*	
	AT-2563-P2			mean	64.47	0.56	16.24	4.30	0.15	1.97	5.57	4.52	1.75	0.31	0.21	98.76	4
				1 δ	*0.12*	*0.05*	*0.31*	*0.13*	*0.10*	*0.05*	*0.07*	*0.11*	*0.03*	*0.02*	*0.18*	*1.62*	
	AT-2563-P3			mean	65.08	0.21	19.28	1.70	0.04	0.65	5.74	5.63	1.41	0.24	0.07	100.57	2
				1 δ	*0.69*	*0.01*	*0.88*	*0.40*	*0.01*	*0.04*	*0.24*	*0.28*	*0.19*	*0.00*	*0.07*	*0.12*	
	AT-2563-P1		Wallace et al. 2014	mean	65.24	0.50	16.48	3.90	0.11	2.00	5.04	4.43	1.84	0.21	0.24	99.48	17
				1 δ	*0.41*	*0.06*	*0.21*	*0.16*	*0.04*	*0.05*	*0.19*	*0.18*	*0.06*	*0.03*	*0.04*		
	AT-2563-P2			mean	75.07	0.20	13.75	1.59	0.07	0.39	2.05	3.78	2.66	0.39	0.05	96.27	12
				1 δ	*0.56*	*0.04*	*0.25*	*0.12*	*0.03*	*0.02*	*0.14*	*0.24*	*0.11*	*0.07*	*0.04*		
11HYKLW001-9	AT-2562-P1	G	This Study	mean	77.56	0.27	11.73	1.45	0.06	0.27	1.48	3.73	2.83	0.59	0.12	96.42	28
				1 δ	*0.85*	*0.03*	*0.55*	*0.16*	*0.06*	*0.08*	*0.30*	*0.46*	*0.14*	*0.07*	*0.17*	*1.25*	
	AT-2562-P2			mean	73.19	0.25	14.28	1.52	0.07	0.53	3.10	4.40	2.23	0.49	0.02	97.32	14
				1 δ	*1.09*	*0.08*	*1.14*	*0.74*	*0.06*	*0.83*	*0.47*	*0.70*	*0.16*	*0.13*	*0.06*	*1.14*	
	AT-2562-P3			mean	68.86	0.15	17.60	0.94	0.03	0.14	4.47	5.75	1.73	0.25	0.11	97.90	2
				1 δ	*0.76*	*0.04*	*0.50*	*0.07*	*0.01*	*0.01*	*0.12*	*0.14*	*0.12*	*0.05*	*0.03*	*0.41*	
	AT-2562-P1		Wallace et al. 2014	mean	77.75	0.27	12.17	1.32	0.09	0.25	1.36	3.43	2.87	0.45	0.05	94.79	26
				1 δ	*0.86*	*0.04*	*0.60*	*0.12*	*0.03*	*0.03*	*0.27*	*0.23*	*0.15*	*0.06*	*0.03*		
	AT-2562-P2			mean	74.59	0.19	14.44	1.16	0.08	0.20	2.47	3.90	2.48	0.44	0.05	97.19	2
				1 δ	*0.32*	*0.05*	*0.29*	*0.04*	*0.02*	*0.01*	*0.23*	*0.17*	*0.05*	*0.06*	*0.00*		
11HYKLW001-8	AT-2561-P1	F2	This Study	mean	72.59	0.27	14.35	1.98	0.07	0.54	2.64	4.50	2.53	0.50	0.09	98.49	31
				1 δ	*0.96*	*0.04*	*0.34*	*0.27*	*0.04*	*0.06*	*0.24*	*0.57*	*0.06*	*0.06*	*0.11*	*1.26*	
	AT-2561-P2				69.37	0.23	16.25	1.73	0.14	0.43	4.12	5.20	2.08	0.40	0.11	100.70	1
	AT-2561		Wallace et al. 2014	mean	74.14	0.21	14.49	1.51	0.09	0.47	2.12	3.93	2.66	0.33	0.06	97.24	29
				1 δ	*0.46*	*0.05*	*0.20*	*0.10*	*0.04*	*0.04*	*0.11*	*0.17*	*0.08*	*0.04*	*0.03*		
11HYKLW001-7	AT-2560	F1	This Study	mean	71.58	0.30	14.50	2.15	0.09	0.62	2.83	4.86	2.51	0.55	0.10	98.70	33
				1 δ	*0.56*	*0.03*	*0.20*	*0.15*	*0.04*	*0.08*	*0.17*	*0.37*	*0.08*	*0.05*	*0.08*	*1.17*	
	AT-2560-P1		Wallace et al. 2014	mean	71.33	0.29	15.70	1.90	0.10	0.59	2.56	4.32	2.68	0.46	0.07	95.11	12
				1 δ	*0.29*	*0.06*	*0.23*	*0.08*	*0.02*	*0.03*	*0.09*	*0.14*	*0.06*	*0.05*	*0.03*		
	AT-2560-P2			mean	72.56	0.28	15.11	1.84	0.09	0.56	2.39	4.10	2.58	0.40	0.08	96.79	9
				1 δ	*0.14*	*0.03*	*0.15*	*0.09*	*0.02*	*0.03*	*0.07*	*0.15*	*0.06*	*0.05*	*0.03*		

[a]USGS AVO sample names; [b]Alaska Tephra Laboratory and Data Center identification number (AT #); [c]Unit refers to unofficially named tephras from the Hayes River Outcrop (of Wallace et al. 2014); [d]Reference for analysis. Reported compositions are weight percent averages of n points, normalized to 100 percent; total gives original sum, 1 σ is standard deviation, not standard deviation of the mean. Raw point data given in supplemental file. P-, population; raw, original raw total.

Table D.1. Comparison of proximal Hayes Volcano tephra analyses reported in this study and in Wallace et al. (2014). Continued from previous page.

Sample Name[a]	AT-#[b]	Unit[c]	Reference[d]		SiO_2	TiO_2	Al_2O_3	FeO_T	MnO	MgO	CaO	Na_2O	K_2O	Cl	P_2O_5	$TOTAL_{raw}$	n
11HYKLW001-13	AT-2565	E	This Study	mean	72.69	0.29	14.31	2.04	0.09	0.55	2.65	4.22	2.57	0.58	0.09	98.23	29
				1 δ	*1.01*	*0.05*	*0.45*	*0.32*	*0.06*	*0.08*	*0.30*	*0.37*	*0.10*	*0.09*	*0.11*	*1.15*	
	AT-2565		Wallace et al. 2014	mean	72.69	0.29	14.76	1.87	0.10	0.59	2.36	4.02	2.79	0.44	0.09	97.03	17
				1 δ	*0.62*	*0.05*	*0.18*	*0.07*	*0.03*	*0.06*	*0.12*	*0.55*	*0.18*	*0.05*	*0.04*		
11HYKLW001-15	AT-2567-P1	D	This Study	mean	74.50	0.24	13.99	1.54	0.08	0.40	2.43	4.12	2.30	0.37	0.08	98.46	32
				1 δ	*2.09*	*0.07*	*0.93*	*0.48*	*0.05*	*0.18*	*0.80*	*0.69*	*0.42*	*0.11*	*0.11*	*1.11*	
	AT-2567-P2				69.91	0.15	17.43	0.79	0.07	0.16	4.22	5.15	1.83	0.28	0.05	95.79	1
	AT-2567		Wallace et al. 2014	mean	73.64	0.21	14.77	1.48	0.08	0.45	2.04	4.35	2.61	0.31	0.07	95.13	15
				1 δ	*0.97*	*0.07*	*0.45*	*0.19*	*0.03*	*0.06*	*0.19*	*0.26*	*0.14*	*0.05*	*0.04*		
11HYKLW001-6	AT-2559-P1	B	This Study	mean	72.49	0.27	14.12	1.86	0.09	0.53	2.60	5.38	2.15	0.42	0.15	99.28	30
				1 δ	*1.39*	*0.04*	*0.42*	*0.32*	*0.04*	*0.09*	*0.36*	*0.56*	*0.12*	*0.07*	*0.18*	*1.09*	
	AT-2559-P2				64.70	0.55	15.93	4.25	0.05	1.80	4.83	5.63	1.76	0.48	0.11	95.81	1
	AT-2559-P3				75.38	0.27	14.23	1.85	0.07	0.51	2.36	2.64	2.15	0.36	0.23	97.93	1
	AT-2559		Wallace et al. 2014	mean	72.83	0.27	15.09	1.81	0.09	0.57	2.52	4.27	2.18	0.29	0.08	98.38	27
				1 δ	*0.44*	*0.04*	*0.31*	*0.13*	*0.04*	*0.04*	*0.10*	*0.20*	*0.07*	*0.05*	*0.04*		
11HYKLW001-5	AT-2558-P1	A	This Study	mean	69.84	0.37	14.95	2.51	0.09	0.77	3.30	5.71	1.95	0.49	0.09	99.71	12
				1 δ	*0.54*	*0.03*	*0.27*	*0.13*	*0.05*	*0.06*	*0.14*	*0.35*	*0.05*	*0.06*	*0.10*	*0.95*	
	AT-2558-P2			mean	72.19	0.28	14.16	1.90	0.10	0.56	2.63	5.43	2.35	0.45	0.02	98.81	12
				1 δ	*0.65*	*0.03*	*0.31*	*0.19*	*0.04*	*0.06*	*0.16*	*0.27*	*0.17*	*0.10*	*0.13*	*1.35*	
	AT-2558-P3			mean	74.93	0.02	14.14	0.51	0.16	0.10	0.68	5.28	3.97	0.07	0.14	95.53	3
				1 δ	*0.06*	*0.01*	*0.09*	*0.05*	*0.01*	*0.01*	*0.06*	*0.15*	*0.08*	*0.01*	*0.13*	*0.04*	
	AT-2558-P1		Wallace et al. 2014	mean	70.84	0.34	15.87	2.18	0.11	0.72	2.97	4.40	2.10	0.34	0.13	97.16	12
				1 δ	*0.24*	*0.05*	*0.17*	*0.13*	*0.05*	*0.04*	*0.07*	*0.19*	*0.06*	*0.04*	*0.03*		
	AT-2558-P2			mean	76.50	0.05	14.65	0.56	0.20	0.11	0.64	3.47	3.58	0.12	0.13	93.02	10
				1 δ	*0.51*	*0.03*	*0.33*	*0.13*	*0.04*	*0.03*	*0.05*	*0.13*	*0.32*	*0.03*	*0.03*		
	AT-2558-P3			mean	72.38	0.24	15.38	1.74	0.09	0.53	2.49	4.07	2.65	0.37	0.06	97.03	4
				1 δ	*0.25*	*0.05*	*0.22*	*0.12*	*0.06*	*0.01*	*0.05*	*0.16*	*0.07*	*0.06*	*0.03*		

[a]USGS AVO sample names; [b]Alaska Tephra Laboratory and Data Center identification number (AT #); [c]Unit refers to unofficially named tephras from the Hayes River Outcrop (of Wallace et al. 2014); [d]Reference for analysis. Reported compositions are weight percent averages of n points, normalized to 100 percent; total gives original sum, 1 σ is standard deviation, not standard deviation of the mean. Raw point data given in supplemental file. P-, population; raw, original raw total.

Table D.2. Similarity coefficients between Hayes Volcano reference tephra analyses reported in this study and Hayes Volcano reference tephra analyses reported in Wallace et al. (2014).

	AT-#[a]	Hayes Volcano tephra analyses reported in this study														
		AT-2564	AT-2563-P1	AT-2563-P2	AT-2563-P3	AT-2562-P1	AT-2562-P2	AT-2562-P3	AT-2561-P1	AT-2560	AT-2565	AT-2567-P1	AT-2559-P1	AT-2558-P1	AT-2558-P2	AT-2558-P3
Wallace et al. (2014) Hayes analyses	AT-2564-H2	0.92	-	-	-	-	-	-	-	-	-	0.93	-	-	-	-
	AT-2563-P1-H1	-	-	0.92	-	-	-	-	-	-	-	-	-	-	-	-
	AT-2563-P2-H1	0.91	-	-	-	-	-	-	-	-	-	0.93	-	-	-	-
	AT-2562-P1-G	-	-	-	-	0.94	-	-	-	-	-	-	-	-	-	-
	AT-2562-P2-G	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	AT-2561-F2	-	-	-	-	-	-	-	-	-	-	0.93	-	-	-	-
	AT-2560-P1-F1	-	-	-	-	-	-	-	0.94	0.92	0.94	-	0.91	-	0.94	-
	AT-2560-P2-F1	0.91	-	-	-	-	-	-	0.93	0.90	0.93	0.91	0.93	-	0.93	-
	AT-2565-E	0.90	-	-	-	-	-	-	0.92	0.90	0.93	-	0.91	-	0.93	-
	AT-2567-D	-	-	-	-	-	-	-	-	-	-	0.92		-	-	-
	AT-2559-B	-	-	-	-	-	-	-	0.91	-	-	0.91	0.93	-	0.91	-
	AT-2558-P1-A	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	AT-2558-P2-A	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	AT-2558-P3-A	0.91	0.90	-	-	-	-	-	0.92	-	0.91	0.93	0.91	-	-	-

[a]Unit refers to unofficially named tephras from the mSRV OR Hayes Volcano proximal tephra as reported in Wallace et al. (2014); [b]Alaska Tephra Laboratory and Data Center identification number (AT #);-value <0.90 and therefore not reported.

Table D.3. Similarity coefficients between mSRV archaeological Devil tephra analyses reported in this study and Hayes Volcano reference tephra analyses reported in Wallace et al. (2014).

	Unit[a] AT-#[b]	Archaeological Devil tephra geochemical populations												
		AT-3184	AT-3181	AT-3194-P1	AT-3194-P2	AT-3194-P3	AT-3205-P1	AT-3205-P2	AT-3221-P1	AT-3221-P2	AT-3221-P3	AT-3221-P4	AT-3442	AT-3445-P1
Wallace et al. (2014) Hayes analyses	AT-2564-H2	-	0.91	-	-	-	-	-	-	-	-	-	-	-
	AT-2563-P1-H1	-	-	-	-	-	-	-	-	-	-	-	-	-
	AT-2563-P2-H1	-	0.92	-	0.91	-	-	-	-	-	-	-	-	-
	AT-2562-P1-G	-	-	-	-	-	-	-	-	-	-	-	-	-
	AT-2562-P2-G	-	-	-	-	-	-	-	-	-	-	-	-	-
	AT-2561-F2	-	0.91	-	-	-	-	-	-	-	-	-	-	-
	AT-2560-P1-F1	-	-	-	-	-	-	-	-	-	-	-	-	-
	AT-2560-P2-F1	0.91	-	0.90	-	-	0.92	-	-	-	-	-	0.91	-
	AT-2565-E	-	-	-	-	-	0.90	-	-	-	-	-	-	-
	AT-2567-D	-	0.91	-	-	-	-	-	-	-	-	-	-	-
	AT-2559-B	0.92	-	0.92	-	-	0.92	-	-	-	-	-	0.91	-
	AT-2558-P1-A	-	-	-	-	-	-	-	-	-	-	-	-	-
	AT-2558-P2-A	-	-	-	-	-	-	-	-	-	-	-	-	-
	AT-2558-P3-A	0.92	0.91	0.93	-	-	0.93	-	-	-	-	0.93	0.93	-

[a]Unit refers to unofficially named tephras from the mSRV OR Hayes Volcano proximal tephra as reported in Wallace et al. (2014); [b]Alaska Tephra Laboratory and Data Center identification number (AT #);-value <0.90 and therefore not reported.

Table D.4. Similarity coefficients between mSRV archaeological Watana tephra analyses reported in this study and Hayes Volcano reference tephra analyses reported in Wallace et al. (2014).

		Archaeological Watana tephra geochemical populations															
	Unit[a] AT-#[b]	AT-3185 Ox	AT-3186 Ox	AT-3444-P1 Unox	AT-3448 Unox	AT-3182	AT-3219 P1	AT-3219 P2	AT-3219 P3	AT-3195 P1	AT-3195 P2	AT-3206 P1	AT-3219 P1	AT-3220	AT-3440	AT-3441 P1	AT-3441-P2
Wallace et al. (2014) Hayes analyses	AT-2564-H2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	AT-2563-P1-H1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	AT-2563-P2-H1	0.90	-	-	-	-	-	0.91	-	-	-	-	-	-	-	-	-
	AT-2562-P1-G	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	AT-2562-P2-G	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	AT-2561-F2	0.90	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	AT-2560-P1-F1	-	-	-	-	-	0.90	-	-	-	-	-	0.91	0.90	-	-	-
	AT-2560-P2-F1	0.90	-	0.91	-	-	0.91	-	-	0.90	-	0.92	0.92	0.92	-	-	-
	AT-2565-E	-	-	-	-	-	0.91	-	-	-	-	0.90	0.91	0.91	-	-	-
	AT-2567-D	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	AT-2559-B	-	-	0.91	-	0.90	0.91	-	-	0.92	-	0.92	0.92	0.92	-	0.90	-
	AT-2558-P1-A	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	AT-2558-P2-A	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	AT-2558-P3-A	0.93	0.93	0.93	0.92	0.93	0.91	-	-	-	-	0.93	0.91	0.91	-	0.94	-

[a]Unit refers to unofficially named tephras from the mSRV OR Hayes Volcano proximal tephra as reported in Wallace et al. (2014); [b]Alaska Tephra Laboratory and Data Center identification number (AT #);-value <0.90 and therefore not reported.

Appendix E

This appendix provides the results of similarity coefficient calculation between multiple samples of the same tephra, which were used determine geochemical populations within individual tephra units from the mSRV, following the protocols of Brochardt (1974). Also provided are tables with the similarity coefficient values and the order that each geochemical population within a given tephra sample was added to a geochemical group being designated for that tephra unit (in parentheses).

Devil Tephra

Table E.1. Results of SIMAN similarity coefficient calculation between all mSRV archaeological Devil tephra geochemical populations.

Archaeological Devil Tephra Geochemical Populations	Archaeological Devil Tephra Geochemical Populations												
AT-#[a]	AT-3184	AT-3181	AT-3194 P1	AT-3194 P2	AT-3194 P3	AT-3205 P1	AT-3205 P2	AT-3221 P1	AT-3221 P2	AT-3221 P3	AT-3221 P4	AT-3442	AT-3445 P1
AT-3184		**0.95**	**0.97**	-	-	**0.99**	-	-	-	-	**0.97**	**0.99**	**0.97**
AT-3181			**0.96**	-	-	**0.95**	-	-	-	-	**0.95**	0.94	**0.97**
AT-3194-P1				-	-	**0.97**	-	-	-		**0.96**	**0.97**	**0.98**
AT-3194-P2					-	-	-	-	-	**0.95**	-	-	-
AT-3194-P3						-	0.93	0.93	-	-	-	-	-
AT-3205-P1							-	-	-	-	**0.97**	**0.99**	**0.98**
AT-3205-P2								0.91	0.91	-	-	-	-
AT-3221-P1									-	-	-	-	-
AT-3221-P2										-	-	-	-
AT-3221-P3											-	-	-
AT-3221-P4												**0.97**	**0.97**
AT-3442													**0.97**
AT-3445-P1													

[a]Alaska Tephra Laboratory and Data Center identification number (AT #).

Table E.2. Establishing Devil tephra group geochemistries.

	AT-#[a]	Devil Geochemical Groups	
		Group 1	Group 2
Archaeological Devil Tephra Geochemical Populatio	AT-3184	**0.99 (1)**	-
	AT-3181	0.95 (6)	-
	AT-3194-P1	0.97 (4)	-
	AT-3194-P2	-	**0.95 (1)**
	AT-3194-P3	-	-
	AT-3205-P1	**0.99 (1)**	-
	AT-3205-P2	-	-
	AT-3221-P1	-	-
	AT-3221-P2	-	-
	AT-3221-P3	-	**0.95 (1)**
	AT-3221-P4	0.97 (5)	-
	AT-3442	0.99 (3)	-
	AT-3445-P1	0.97 (2)	-

[a]Alaska Tephra Laboratory and Data Center identification number (AT #).

Results of SIMAN similarity coefficient calculation for Devil geochemical groups 1 and 2, and order in which individual Devil tephra sample geochemical populations were added to the Devil tephra unit geochemical groups (in parentheses).

Watana Tephras

Table E.3. Results of SIMAN similarity coefficient calculation between all mSRV archaeological Watana tephra geochemical populations.

AT-#[a] (Archaeological Watana Tephra Geochemical Populations)	AT-3185	AT-3186	AT-3444-P1	AT-3182	AT-3192 -P1	AT-3192-P2	AT-3192-P3	AT-3195-P1	AT-3195-P2	AT-3206-P1	AT-3219-P1	AT-3220	AT-3440	AT-3441-P1	AT-3441-P2	AT-3448
AT-3185		**0.99**	**0.98**	**0.98**	0.95	-	-	0.93	-	**0.96**	0.94	0.95	**0.96**	**0.98**	-	**0.97**
AT-3186			**0.98**	**0.98**	**0.95**	-	-	0.94	-	**0.97**	**0.95**	**0.95**	**0.97**	**0.98**	-	**0.97**
AT-3444-P1				**0.99**	**0.96**	-	-	0.94	-	**0.97**	**0.96**	**0.96**	**0.97**	**0.99**	-	**0.98**
AT-3182					**0.96**	-	-	0.95	-	**0.98**	**0.96**	**0.96**	**0.97**	**0.98**	-	**0.97**
AT-3192-P1						-	-	**0.97**	-	**0.98**	**0.98**	**0.99**	**0.98**	**0.96**	-	**0.96**
AT-3192-P2							-	-	-	-	-	-	-	-	-	-
AT-3192-P3								-	-	-	-	-	-	-	0.92	-
AT-3195-P1									-	**0.96**	**0.97**	**0.98**	**0.96**	0.94	-	0.94
AT-3195-P2										-	-	-	-	-	-	-
AT-3206-P1											**0.98**	**0.98**	**0.99**	**0.98**	-	**0.97**
AT-3219-P1												**0.99**	**0.98**	**0.96**	-	**0.96**
AT-3220													**0.99**	**0.96**	-	**0.96**
AT-3440														**0.97**	-	**0.97**
AT-3441-P1															-	**0.98**
AT-3441-P2																-
AT-3448																

[a]Alaska Tephra Laboratory and Data Center identification number (AT #).

Results of SIMAN similarity coefficient calculation between all mSRV archaeological Watana tephra geochemical populations.

Table E.4. Establishing Watana tephra group Geochemistries.

	AT-#[a]	Watana Geochemical Groups		
		Group 1 (oxid-ized)	Group 2 (un-oxidized)	Group 3 (entire deposit)
Archaeological Watana Tephra Geochemical Populations	AT-3185	**0.99 (1)**	-	0.98 (4)
	AT-3186	**0.99 (1)**	-	0.98 (3)
	AT-3444-P1	-	**0.98 (1)**	0.99 (2)
	AT-3182	-	-	**0.99 (1)**
	AT-3192-P1	-	-	0.97 (9)
	AT-3192-P2	-	-	-
	AT-3192-P3	-	-	-
	AT-3195-P1	-	-	0.95 (12)
	AT-3195-P2	-	-	-
	AT-3206-P1	-	-	0.97 (6)
	AT-3219-P1	-	-	0.97 (10)
	AT-3220	-	-	0.96 (8)
	AT-3440	-	-	0.97 (7)
	AT-3441-P1	-	-	**0.99 (1)**
	AT-3441-P2	-	-	-
	AT-3448	-	**0.98 (1)**	0.98 (5)

[a]Alaska Tephra Laboratory and Data Center identification number (AT #).

Results of SIMAN similarity coefficient calculation for Watana geochemical groups. Watana geochemical groups 1 and 2 and based on stratigraphic position (oxidized and unoxidized) whereas group 3 considers ambiguous Watana tephra samples. The order in which individual tephra sample geochemical populations were added to unit geochemical groups are noted in parentheses.

Oshetna Tephra

Table E.5. Results of SIMAN similarity coefficient calculation between all mSRV archaeological Oshetna tephra geochemical populations.

		Archaeological Oshetna Tephra Geochemical Populations													
	AT-#[a]	AT-3188-P1	AT-3188-P2	AT-3188-P3	AT-3188-P4	AT-3183 P1	AT-3183 P2	AT-3183 P3	AT-3183 P4	AT-3193 P1	AT-3193 P2	AT-3193 P3	AT-3196 P1	AT-3196 P2	AT-3196 P3
Archaeological Oshetna Tephra Geochemical Populations	AT-3188-P1		-	-	-	-	-	-	0.90	-	-	0.92	-	-	-
	AT-3188-P2			-	-	-	-	0.94	-	0.94	-	-	-	-	-
	AT-3188-P3				-	-	-	-	-	0.91	-	-	-	-	0.93
	AT-3188-P4					-	-	-	-	-	-	-	-	-	-
	AT-3183-P1						-	-	-	-	-	-	-	0.94	-
	AT-3183-P2							-	-	-	**0.96**	-	**0.98**	-	-
	AT-3183-P3								-	0.93	-	-	-	-	-
	AT-3183-P4									-	-	0.92	-	-	-
	AT-3193-P1										-	-	-	-	-
	AT-3193-P2											-	**0.96**	-	-
	AT-3193-P3												-	0.92	-
	AT-3196-P1													-	-
	AT-3196-P2														-
	AT-3196-P3														

[a]Alaska Tephra Laboratory and Data Center identification number (AT #).

Results of SIMAN similarity coefficient calculation between all mSRV archaeological Oshetna tephra geochemical populations.

Table E.6. Establishing Oshetna tephra group geochemistries.

Archaeological Oshetna Tephra Geochemical Populations	Oshetna Tephra Geochemical Groups			
AT-#[a]	Group 1	Group 2	Group 3	Group 4
AT-3188-P1	-	-	-	**0.92 (1)**
AT-3188-P2	-	**0.94 (1)**	-	-
AT-3188-P3	-	0.90 (3)	-	-
AT-3188-P4	-	-	-	-
AT-3183-P1	-	-	**0.94 (1)**	-
AT-3183-P2	**0.98 (1)**	-	-	-
AT-3183-P3	-	0.93 (2)	-	-
AT-3183-P4	-	-	-	0.91 (2)
AT-3193-P1	-	**0.94 (1)**	-	-
AT-3193-P2	0.96 (2)	-	-	-
AT-3193-P3	-	-	-	**0.92 (1)**
AT-3196-P1	**0.98 (1)**	-	-	-
AT-3196-P2	-	-	**0.94 (1)**	-
AT-3196-P3	-	-	-	-

[a]Alaska Tephra Laboratory and Data Center identification number (AT #).

Results of SIMAN similarity coefficient calculation for Oshetna geochemical groups; the order in which individual Oshetna tephra sample geochemical populations were added to Oshetna tephra unit geochemical groups are noted in parentheses.